Wm. Constable Esqr.
F.R.S. & F.A.S.

AN

INTRODUCTION

TO A GENERAL

SYSTEM

OF

Hydroſtaticks and *Hydraulicks*,

PHILOSOPHICAL and PRACTICAL.

WHEREIN

The moſt reaſonable and advantageous METHODS of raiſing and conducting Water, for the watering Noblemens and Gentlemens Seats, Buildings, Gardens, *&c.* are carefully (and in a Manner not yet publiſh'd in any Language) laid down.

CONTAINING IN GENERAL

A Phyſico-mechanical Enquiry into the Original and Riſe of SPRINGS, and of all the Hypotheſes relating thereto; as alſo the Principles of Water-works, and the Draughts and Deſcriptions of ſome of the beſt Engines for raiſing and diſtributing WATER, for the Supply of Country Seats, Cities, Towns corporate, *&c.*

Deduc'd from the Theory of *Archimedes*, *Gallileo*, *Torricelli*, *Boyle*, *Wallis*, *Plot*, *Hook*, *Marriotte*, *Deſaguliers*, *Derham*, *Hawksbee*, and others.

Reduc'd to Practice by *Vitruvius*, *Bockler*, *de Caus*, and other Architects amongſt the ancient *Romans*, *Italians*, *French*, *Flemmings*, and *Dutch*, and much improv'd by later *Practice* and *Experience*.

Illuſtrated and Explain'd by Sixty Copper Cuts, done by the beſt Hands, of the *Principles* which tend to the Explanation of the whole, and of rural Groteſque, and cheap Deſigns for Reſervoirs, Cataracts and Caſcades of WATER, Canals, Baſins, Fountains, *&c.* Collected from the beſt of the *Italian* and *French* Deſigns (together with ſome new ones of the Author's own Invention) few of which have ever appear'd in Books of Hydroſtaticks, *&c.*

VOLUME II.

By *STEPHEN SWITZER.*

Sunt quippe (Hydroſtaticæ) *artis theoremata & problemata maximam partem genuina & pulchella ſoboles rationis circa argumenta attente penſitata rite ſe exercentis.* —— *Etenim complura ſunt, non ex familiaribus moda ſua, & abſtruſioribus naturæ Phænominis quæ nunquam Capientur penitus neque Explicabuntur dilucidè ab iis qui hoſpites ſunt in Hydroſtaticis; a quorum Principiis pendent, &c.*

Boyle's Paradox. Hydroſtat. Præfat.

LONDON.

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TO THE

RIGHT HONOURABLE

WILLIAM,

Baron and Earl of *Inchiquin*,

Baron of Burren *in the Kingdom of* Ireland, *and Knight of the most Honourable Order of the* Bath.

MY LORD,

THE greatest Success I can promise myself (next to the sincere Endeavours I have been at in making these Volumes of *Hydrostaticks* and *Hydraulicks* diverting and useful to the World) is the Happiness I enjoy of presenting them to the Patronage and Protection of Noblemen, who may (with so much Justice) be plac'd amongst the most benevolent and friendly Patrons of Mankind, and from whom I have received such repeated Marks of Favour and Friendship.

I KNOW not well, my Lord, what kind Luminary it was which directed me to the Felicity, I am now acknowledging: But the Reflection thereon is ſuch as (I muſt with Gratitude own) warms my Imagination, and poliſhes the rugged Face of thoſe Difficulties, with which Perſons in my Sphere are unavoidably attended; and my Happineſs is ſtill heightened, when, to the Friendſhip before-mentioned, I add that of your Lordſhip's Affection to all thoſe uſeful Improvements, which for ſo many Years have been the Subject of my Attention and Study. Perſons of your Lordſhip's Figure in the World, are like the Sun (the principal Subject of all our Philoſophical Enquiries) which, tho' plac'd at ſo immenſe a Diſtance above this lower Region; yet, by the great Influence it has over ſublunary Beings, diſpels the gloomy Shades of the Night, and introduces the Gaiety of the lovely Day.

THE Subjects I here preſent your Lordſhip with, as they are of the greateſt Importance to the vegetable and animal Life; ſo they juſtly furniſh its Obſervers, with ſome of the moſt exterior, deepeſt, and moſt philoſophical Reſearches, of any in the whole Boſom of Nature, as well as the Proſpect of ſome of the exterior, and moſt ſtupendouſly amazing of all her Works. 'Tis the Contemplation of theſe Objects, which raiſes an uncommon Pleaſure in the Imagination, and fills the Soul with Ideas, Great and Noble as itſelf.

WHAT more admirable than an Enquiry into the Being and Actions of thoſe Powers, by which this ſeemingly indiſſoluble World is (by a due and regular Circulation) upheld and maintain'd; and at the Ceſſation of which, Nature would ſoon be reduc'd to the greateſt Agonies

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nd Convulſions, and be forc'd to ſubmit to her primitive Nothing.

WHAT more magnificent than thoſe voluminous Scenes and Ridges of Mountains and Hills involv'd in one another, and ſpouting out Rivers for the Supply of Mankind! Landskips ſo truly magnificent and great, that they fling the Imagination into thoſe pleaſing Aſtoniſhments, which the Vivacity of ſuch Objects, the precipitate Cadences of Fountains, Cataracts and Caſcades of Water, affords to its admiring Spectators (permit me, my Lord, to tranſcribe the Words of one of the beſt Authors of this or the laſt Age) *ſuch Proſpects are as pleaſing to the Fancy, as the Speculations of Eternity and Infinitude are to the Underſtanding, the Beholder is quickly tired with Hills and Vallies, where every thing continues fix'd, and ſettled in the ſame Place and Poſture, but his Thoughts are always relieved at the Sight of ſuch Objects as are ever in Motion, and ſliding away from his Eyes.* And truly, my Lord, whatever the Opinion of ſome Moderns may be, who decry Water as too aguiſh and cold for this Region and Climate; yet I humbly conceive, that wherever its Current or Paſſage is ſwift, and thereby free from Stagnation, nothing in Nature can be more pleaſant, nor any Seat compleat without it

IT is this (may I continue the Words of that learned Author) *which ſerves for a continual Refreſhment, and takes off from that Satiety, of which Mankind are too apt to complain; it is this, that beſtows Charms upon a Monſter, and makes even the Imperfections of human Nature pleaſing; it is this that recommends Variety, where the Mind is continually taken up with ſomething that is old,*

or

or called off to what is new. It is ſuch enlarged and noble Objects which enlarge the Mind anew; nor can there be any thing more enlivening to the Fancy, than the Proſpect of Rivers, Jet-d'eaux or Falls of Water, when diſpoſed well, and at proper Diſtances.

How well, my Lord, I have acquitted myſelf in the Purſuit of theſe noble Objects and Enquiries, muſt be left to the Deciſion of this diſcerning Age. Thus much is certain, that what Judgment ſoever is paſs'd upon the Perfections or Imperfections of this Undertaking, the World will be oblig'd to own, that I can diſtinguiſh well in the Choice I have made of preſenting theſe Papers to your Lordſhip, and that I am more than happy in the Pleaſure (I am allow'd) of ſubſcribing myſelf,

My LORD,

Your Lordſhip's Moſt Obliged,

Moſt Obedient

Humble Servant,

STEPHEN SWITZER.

ADVERTISEMENT

TO

The SECOND VOLUME.

THAT the Reader may be ſatisfy'd why this Work is divided into two Volumes, rather than bound up in one, as was at firſt intended, it will be proper (I humbly conceive) in this Place to acquaint him, that the Length of the Subject, and the great Number of the Cuts, have made the Bulk of the Book much larger than at firſt it was ſuppos'd it would; and that if it had been bound up in one Volume, it would have been too cumberſome, and the Difficulty of folding and unfolding of the Cuts would have been troubleſome: On which Account, it was thought proper to divide it into two Volumes; but ſo as to maintain the ſame running Title, and to break off at a Place where the Cuts would come in ſo well, as to finiſh and compleat this ſecond Volume, without any great Enlargement of the Price, or any other Detriment to the curious Reader.

THE Author alſo takes this Opportunity of acknowledging the Obligations he has to thoſe Noblemen and Gentlemen, by whoſe generous Subſcription this Deſign was firſt ſet on Foot, but which, by reaſon of the Multiplicity of other Buſineſs in which he is employ'd, and the Tedіouſneſs of collecting Subſcriptions equal to ſo expenſive a Work as this was found to be, he has deſiſted from that Method of printing it, and has not thought it proper to print the Names of thoſe who did him that Honour, becauſe he had not Time to collect them from but few; but thus far he promiſes in Acknowledgment of their Favours, that ſuch Subſcribers ſhall not only have the very firſt Cuts of all the Impreſſion, but ſhall alſo have the Book at a more reaſonable Rate than thoſe who did not ſubſcribe. From the Conceitedneſs of ſome part of the World, and the ill Nature of others, I am perſwaded how different the Reception of this, as well as other Works, will be, according as the Humor or Intereſt of different Parties prevail.

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ADVERTISEMENT.

ONE of the greateſt Objections I foreſee (and which indeed I hear of already) is, that a Work of this kind is not the proper Province of a Gardener, and that perhaps he might as well have employ'd himſelf in writing of Aſtronomy, or any other abſtruſe Science. To theſe I anſwer, that the Study of Hydroſtaticks does more particularly belong to a Gardener, than to any other Perſon whatſoever; whether it be conſidered in a Philoſophical Senſe, as it gives him an Inſight into the Proceſs of Nature in Vegetation, the Aſcenſion, Receſſion, or progreſſive Motion of Sap in Plants; or in a Mathematical Senſe, as it ſerves, for the Embelliſhment of a Country Seat with Water; or of both, as it contains a Reſearch into the Gravity, Elaſticity and Progreſs of Air, and other Fluids, ſo neceſſary for the Preſervation of the vegetable, as well as animal World; nor can an Eſſay of this Kind, if well endeavoured at, be, I humbly hope, by thoſe who are impartial, thought out of the Way, let it come from what Hand it will.

ALL that I have to add, is, That I have ſpared no Pains in making this Collection as uſeful as I poſſibly could, for the Service of the World; and if I have fallen ſhort of the Dignity of the Subject, or have been wanting in the Extraction I have made from other Authors, the good natur'd Reader will, 'tis humbly hop'd, aſcribe it to Hurry rather than Neglect in the Author.

AN INTRODUCTION TO A General SYSTEM OF HYDROSTATICKS and HYDRAULICKS.

BOOK III.

CHAP. XX.
Of Hydraulicks, *its Etymology*, &c.

THE Etymology or Derivation of *Hydraulicks*, (tho' it is a Word rarely found in any of the Lexicons) is undoubtedly from ΥΔΩΡ, or rather ὑδρὸς *aqua*, Water, or of, or belonging thereto; and αὐλὸς *Tibicen*, or *Tibia*, a Pipe: Since *Vitruvius*, *Lib.* 10. *chap.* 12. tells us, that the Ancients heretofore play'd all their Organs and other Instruments of Musick of that kind (which we now play with Wind) by Water.

" THE Organs, (says he) were play'd by the Help of two Suc-" kets, which were pull'd up or let down in the Body of the Pump, " which Suckets press'd the Air with Violence into a Funnel revers'd " in a Copper Coffer, half full of Water, and press'd the Water, " and constrain'd it so as to ascend round about within the Coffer, " which operated so, that its Weight in making it re-enter into the " Funnel, push'd the Air into the Pipes, and made them play, pro-" ducing the same Effects which the Bellows did.

THE learned *Harris*, in his *Lexicon Technicum*, says, that *Ozanam* is mistaken when he mixes and confounds *Hydrostaticks* and *Hydraulicks* one with another, since by the first is explain'd the natural

Equilibrium or Motion of Water and other Fluids, and by the latter the Force of Mechanical Engines for the forcing it up to great Heights.

And theſe Engines are of many and different Kinds; as Firſt, thoſe that are ſimple, as is the Siphon, Syringe, Antlia, or Single Pump, Screw Engine, and the like.

The ſecond are thoſe that are compounded of the Pump and other Parts; as the Chain-Pump, Crankwork, Vibrating-Leaver, *&c.* the Wheels whereof are drove either by the Strength of Men, Horſes, Water, Wind, and the like.

The laſt is the Fire-Engine; an Invention of that great Uſe and Facility of working (eſpecially in Coal-Mines) where it was at firſt chiefly deſign'd; ſo that we may, without Arrogance, challenge the whole World for ſuch an Invention.

It is requir'd in an Engine, that the Parts, whereof it is compos'd, be few, and thoſe very ſimple and plain; for although in all other Machines, as the Jack, Clock, and Watchwork, as alſo in raiſing a great Weight, there is a Neceſſity of a great Number of Wheels and Pullies, either to retard its Motion, and to keep it long from going down, or in the other Caſe, to make the Aſcent of heavy Bodies more eaſy and regular; to which muſt be join'd, a moſt powerful Force. Yet in Machines for raiſing Water, the Caſe is alter'd. And the Friction is ſo great in a great Number of Cogg-Wheels, Runlets, *&c.* that the Machine goes heavy, and its Imperfection is diſcover'd by that ſhocking and Noiſe which it makes, whilſt a good Machine goes eaſy and ſmooth, and almoſt as ſilent as a Clock or a Watch, as whoever has ſeen that in *Blenheim* Bridge, can teſtify.

The Ancients, as *Vitruvius, lib.* 10. *cap.* 21. ſets down, had ſeveral ſorts of Engines for raiſing of Water.

The firſt was the Tympan, of which there were two Sorts; one elevated a great deal of Water, but not very high, for it only mounted to the Axletree of the Tympan, which was a great Wheel made of Planks, which made two Bottoms divided into eight Parts from the Center to the Circumference, each Separation having an Opening half a Foot wide, near the Circumference, to draw the Water, which being elevated on the Axletree, ran through the Cavities which were hollowed in each Separation.

The ſecond Machine was a Wheel which elevated the Water as high as its Circumference, by the Help of ſeveral Boxes, which were faſtened about it, and which pour'd out the Water into a Reeve, as the Wheel (having mounted) began to deſcend.

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The third Machine was a Chain with Buckets, as the one mounted, the other deſcended, being drawn by the Axletree.

The fourth Machine was the Vice or Screw of *Archimedes*, with which, it was ſaid, he drain'd off the Floods of the *Nile*, though *Vitruvius* makes no mention of the Inventor. This Vice was made of a long Beam, or Piece of Wood, ſixteen Times as long as its Diameter; about this Piece of Wood was put obliquely, a Hoop of Willow Wood, beſmear'd with Pitch, and it was conducted by turning it round, by the Means of a Handle or Wheel, the Bottom of which was fix'd in the Water, and the Top on a Poſt ſet to the Height, to which a Man was to raiſe his Water; and of this Kind there are ſeveral now in Uſe. But of this more in its proper Place.

But beſides this, the Ancients had Engines for drawing or raiſing, which they call'd by the general Name of *Budromia* (as may be ſeen in the Chapter, where the Axis in *Peritrochio* is treated of) and were no other than for the drawing of Water out of Wells by a Chain and Bucket: But as all Engines of this Kind are now reduc'd into a more mechanical Method, they are now rank'd under the general Head of *Hydraulicks*, as has been ſet down more at large in the Beginning of this Book.

Of this Kind there were Engines, Machines or Mills, call them which you will, chiefly made Uſe of then, for the grinding of Corn amongſt the *Romans*, which, as *Vitruvius*, *Lib.* 10. *Chap.* 10. ſays, were mov'd by the Help of a great Wheel, which had many Wings, which we now call Pallats or Ladles, and forced by the Current.

The Axletree of this great Wheel travers'd another which had Coggs, that made the Lanthorn or Trundle Head go round, and which being plac'd horizontally, was travers'd with a Beam of Iron, which entring through above into an Iron in the Form of a Wedge, helped to faſten the Beam into the Millſtone, above which was the Mill-hopper, in form of a Funnel. And thus far *Vitruvius* ſets down, as to Mills, &c. chiefly uſed in thoſe Times, for grinding of Corn, and ſometimes for raiſing of Water: But later Experience has produc'd a much greater Number of Inventions, for raiſing of Water by Chain-work, Crank-work, the vibrating Leaver, Fire Engines, of which in their reſpective Order.

But before I finiſh this Introduction, tho' it is a little facetious, I can't but preſent my Reader with the following Account, as it was ſent me by a Gentleman of Wit and Humour.

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I need not trouble my Reader with the Names of Perſons, unleſs I have Particular Orders for ſo doing, but hope he will take the Letter juſt as he finds it, as it demonſtrates the ſeveral Uſes to which Water Engines may be apply'd.

March 18th, 1727.

SIR,

"SIR *THOMAS* laid his Commands upon me, to give you an "Account of the Water-works by him deſign'd, which comes "from a Spring a Mile from his Hall, with a natural Deſcent all "the Way, at leaſt above 60 Feet high, falling naturally into the "ſeveral uſeful Offices following, *viz.*

"*1ſt*, It ſerves a very fine Marble, but unuſual Beaufet to "waſh his Glaſſes, and which will hold above nine Bottles, at leaſt "half Way in Water to cool his Liquor.

"*2dly*, The next ſerves to turn the Spitt in his Kitchen, by "which, inſtead of a Jack (and much more uſeful, and leſs "troubleſome) he roaſts all his Meat.

"*3dly*, Another large Cock in his Kitchen, which ſerves all common Uſes in the ſame.

"*4thly*, A Cock that turns in a Tubb, to keep the Wort "cool in the ſame, to condenſe the Spirits from a Bolt-head "ſtill.

"*5thly*, The next is the Brewhouſe, where it ſerves 4 Cop-"pers, the firſt plac'd 20 Feet high, to keep Water hot all the Day "for brewing, maſhing, and ſcalding of Veſſels, and which falls "into the maſhing Tubb, and from out of the maſhing Tubb "into the under Deck, from thence into another Copper to boil "the Wort, and from thence into a large Cooler, naturally by "Deſcents, without either pumping or leading.

"*6thly*, And *laſtly*, (at preſent) in his lower Kitchen it roaſts "his Meat (as in the upper Kitchen), churns his Butter, dreſſes the "Flower for his Bread, waſhes his Cloaths, grinds his Malt. And "now give me Leave to add a *7th*, upon the Anvil not yet "brought to Perfection, which will be neceſſary and very uſeful, "being lately married to a fine young Lady, and which he is "now contriving, will be to rock the Cradle.

And with this I ſhall conclude what I have to ſay in this Introduction.

CHAP.

CHAP XXI.

Of the mechanick Sciences, and their Uſes in Hydraulicks, *&c.*

HITHERTO we have treated in general concerning Air and Water, and the natural Effects they have in *Hydroſtaticks* and *Hydraulicks;* but as the latter is principally founded on Mechanicks, in order to the raiſing of Water ſo much above its natural and common Level, to the Tops of high Hills and elevated Situations, it ſeems requiſite that we take ſuch a View of theſe Sciences, as may (with the greater Certainty and Facility) introduce the Reader into that which is the chief Purport of this part of my Deſign ; I mean *Hydraulicks.*

Of the Leaver.

THE firſt I ſhall begin with, is *Vectis*, the Leaver, which, as the learned *Wallis* has it, has its Derivation *à Vehendo*, and that *Vector Vectio, Vectura, Vectigal, Convexum, Vexum, Vexillum*, are a-kin to it; and that it is called Leaver *à Levando*, becauſe of its Uſes in lifting or heaving.

Now the Power of this Inſtrument (which is of great Uſe in *Hydraulicks)* is more or leſs, according to the Point by which it is ſuſpended: For Example, let A B, *Fig.* 1. *Tab. ſeq.* be the Leaver, O the Burthen to be mov'd, B the Point where it is to raiſe its Weight, A the Place where the moving Force is apply'd, and V the Force it ſelf, F the *Fulcrum* or Prop by which it is ſuſtain'd, and C the Center of Motion.

IT is plain, that if that Center or Point of Motion were plac'd more up towards V and A as at D, that the Weight O, which is plac'd at B, could not be rais'd with that Eaſe which now it is, no, not although there were four times the Weight apply'd at A. This is further demonſtrated, by *Fig.* 2.

It would be foreign to my Purpoſe, at leaſt it would take up more Room than I can allow my ſelf in the Compaſs of this Treatiſe, to go through all the Uſes of this ancient, but plain Inſtrument; and for the farther Satisfaction of thoſe that are very curious of my Readers, I refer them to that elaborate Treatiſe of Mechanicks wrote by the learned Dr. *Wallis*, *cap.* 6. *p.* 572, &c. where it is very exactly treated of.

This Leaver we have been thus epitomizing, is alſo not improperly call'd a Scale or Ballance, which is a rectilinear Beam, as A B, *vid. Fig.* 3. made of a firm homogeneous Matter, every where of an equal Thickneſs, ſo that if it reſt with its middle Point C upon the Prop D, its Ends will keep an horizontal Poſition; for which Reaſon it may be conſider'd, as a Line without Weight. And if at equal Diſtances in A and B, or nigh A and B, the equal Weight X and Z be ſuſpended immediately, or within two Baſins of equal Poiſe, they will keep the ſame Situation.

But if the Weight X were to be heavier than the Weight Z, or the Prop at C were to be mov'd more towards either X or Z, then would appear that famous but yet intelligible Theorem, and which is indeed the Corollary of all the Experiments that can be try'd in Mechanicks, *that equal Weights ſuſpended at unequal Diſtances, nor unequal Weights plac'd at equal Diſtances, can't equiponderate.*

And from thence may be demonſtrated, wherein the comparative Habit of Weights, ſuſpended from an unequal Radius of the Ballance, does conſiſt; for if the Weights M N, *Fig.* IV. are reciprocally proportionable to the Parts of the Beam, that is, if the Radius A C be two, and B C three Parts in Length, and again the Weight ſuſpended at the End of the long Radius be two, and M hanging at the ſhorter End be three Pounds, theſe Weights will neceſſarily equipoiſe each other, as Experience ſheweth; for M cannot deſcend, but that N muſt at the ſame time aſcend; nor can the Radius C A in deſcending paſs through two Parts of Space A C; but the longer C B will aſcend through three Parts of Space to F. And ſince the two Pounds Weight N meets with the Reſiſtance of a ſixfold Impulſe in paſſing through the triple Space B F, the three Pound Weight M moving in a double Space, will likewiſe ſuffer a ſextuple Impulſe. And thus it is plain, that it will be ſo in all other Caſes, and therefore the Reſiſtance of the aſcending Weight will be equal to the Impulſes of the deſcending. Hence alſo it is manifeſt, that N cannot be lifted up by M, (nor M by N) for the ſame Reaſon; and conſequently they will mutually keep one another at Reſt in Equilibrio, as

as is in *Fig.* 3. Which being thus demonſtrated, it neceſſarily follows, *that equal Weights ſuſpended at unequal Diſtances from the Middle of the Ballance, can't equiponderate, as before.* For in the preſent Caſe, if to the Weight N never ſo little Weight more be added, it will neceſſarily deſtroy the Equilibrium; how much more, then, will it be taken away, if N by a farther Addition, (*viz.* that of a whole Pound) be ſuppos'd to be made equal to the Weight M?

But if inſtead of the Weight N, ſome other moving Force, eſpecially that of a Man's Hand, were apply'd, then this Ballance returns to its firſt Appellation; the *Vectis* or Leaver not any ways differing from the Ballance in any eſſential Property.

And if the moving Force, being ſomething ſtrongly actuated, move downwards, and the Weight to be mov'd at the ſame time be lifted upwards, the Leaver is then call'd *Heterodromus;* but if one of its Extreams C, (*Fig.* V.) be placed upon the *Hypomochlion,* or Prop, and the other be apply'd to the moving Force B, the Weight to be moved being placed between them both in A; ſo that the moving Force B muſt move the ſame Way with the Weight A, which is to be rais'd, then this *Vectis* or Leaver is call'd *Homodromus.* In which the Proportion of the Diſtances from the *Hypomochlion* or Prop are ſtill the ſame; *viz.* B C being to A C reciprocally as the Weight and Forces, *viz.* as A is to B. For if at one End of the *Hypomochlion* or Prop, there be placed the Radius C *b* equal to C B, it is plain from the Nature of the Ballance, that the Weight of one Pound in *b*, to which the Weight A of four Pounds may be ſuppos'd to be equal in poiſe (by what has been already ſaid) may be ſuſtain'd and kept up by the Force of one Pound apply'd in B, (there being no Weight at the ſame time in A) that is, in plain Terms, the Force of one Pound on B weighs as much as four Pounds in A.

And if the Arms or Radii of the Leaver lie not in a ſtrait Line, but incline one to another, ſo as to make an Angle, the reciprocal Proportion of the Weight and Radii will not then be the ſame, but then the Proportion of the Weights X and Z (*Fig. 6.*) is eſtimated by the Diſtances of the Line of Direction; that is, as if B C, in *Numb.* 1. and A C, in *Numb.* 2. were the Arms or Radii of a rectilinear *Vectis,* and after the ſame Manner, if to one of the Radii D C of the ſtrait *Vectis* or Leaver, there be apply'd a Force drawing upwards or downwards obliquely, *Numb.* 3, and 4. then it will not be as D C is to B C, but as A C to B C. *viz.* the perpendicular Diſtances to the Lines of Direction: So will the Weight Z, which is the Weight to be poiſed, be to the Force that raiſeth it in X, which is ſeldom obſerv'd in vulgar Books of Mechanicks.

After the ſame Manner alſo, may Cranes, with which is drawn the Water out of Wells, be reckoned as Leavers; for in letting down the Bucket E, *Fig.* XI. the Force drawing the Chain or Rope B E downwards, and the Weight it ſelf of the empty Bucket, is apply'd to the longeſt Arm of the Leaver B C, whilſt the Stone D, which is heavier than the Bucket, lies upon the ſhorteſt C A; ſo that the Force drawing down the Chain, is requir'd to be ſo much the leſs, to overcome the Exceſs of the Weight D above the Weight of the Bucket and Chain, by how much the greater the Proportion of the Arm or Radius B C is to the Arm C A; but in drawing up the Bucket, which is now ſuppos'd to be full of Water, the Force that lifts it up, is in part, the Weight of the Stone D, but is apply'd to the ſhorteſt Arm of the inverted Leaver A C: whence it is, that if at moſt the Stone D were equal in Weight to the full Bucket, yet it could not raiſe it up, till, on the other Hand, ſome other Force, *viz.* that of a Man, be apply'd to the Chain, which may be able to outlift the remaining Part of the depreſſing Force or Weight; which Thing is elegantly enough demonſtrated by *Ariſtotle*, *Problem* 28. but yet may be ſet into a clearer Light, if we reduce it into Number, by forming it into ſome Caſe.

As for Example, ſuppoſe the Weight of the empty Bucket and Chain together to be forty Pounds, and the Stone D an Hundred Pounds, the Arm B C as two Pounds, the Arm A C as one Pound; which being ſuppos'd, the Force of a little above thirty Pound will be ſufficient to ſink the Pail; and, on the contrary, let the full Bucket, with its Chain, weigh ninety Pounds; which being ſuppos'd, the Weight ninety Pounds will be to the Weight an Hundred and eighty Pounds, as one to two; and therefore the Stone D, which is an Hundred Pounds, won't be ſufficient to ſuſtain, much leſs to raiſe the Bucket; but the Force of a Man equivalent to above eighty Pounds, is required to draw the Chain up, or to the Weight D there muſt be added ten or twenty Pounds, or elſe the Diſtance from C to A muſt be enlarg'd, or the Proportion from B to C diminiſh'd. But the firſt is the moſt eligible; where, if you apply a Lead Weight of fifty Pounds at C, it will add more Force at that Diſtance, than the Stone of an Hundred Pounds at D; of which more hereafter.

Of the Axis *in* Peritrochio.

The Axis in *Peritrochio*, is a Machine, or Mechanical Inſtrument, proper for lifting great Weights, as the *Vectis* or Leaver is of ſmall; and all Writers of Mechanicks reduce them both to one and the ſame Laws. It is (as the learned Dr. *Wallis* defines it, *cap.* 7. *p.* 605. of his Mechanicks) compos'd of a Cylinder, which is call'd the Axis, and which is ſuſtain'd at each End with a *Hypomochlion*, *Fulcrum*, or Prop, call it which you will; round which, is a *Tympanum*, Wheel, or Crane, and is call'd the *Peritrochium*; in the Ambit or Circumference of which, Holes being made on purpoſe, are fixt in the *Scytalæ*, ſerving as Handles; to which, if a Force is apply'd, the *Peritrochium*, with its Axis, will turn round, on which the Ropes being rowl'd, they elevate or lift up the Burthen.

I shall not copy or tranſlate what that learned Gentleman before-nam'd, or others, have ſet down as to the Original of the ſeveral Members of which this and the other uſeful Inſtruments of this kind are made, becauſe it would lead me too far out of my Way; but in order to illuſtrate it the better, will, for example, ſuppoſe the cylinderical Axis to be moveable horizontally, about the central Pins or Nails at A B, (*Fig.* VIII.) to which a Rope being faſtened by one of its Extreams, and wound round the Cylinder or Axis, having a Weight hanging at the other End, it will raiſe it ſo much the faſter, by how much the oftner the Cylinder is turn'd round; for the facilitating of which, either one Leaver D A is tranſverſly inſerted into it, which muſt be turn'd round with a Man's Hand, or any other impelling Force, from D to *d*, &c. and ſo rendered perpetual, and ſometimes for Conveniency, two, at leaſt, are put in, as 𝔇 𝔄 ℭ and *d* A *c*, are tranſverſly thruſt through it, whoſe Extremities 𝔇 *d* ℭ and *c*, may be ſucceſſively turn'd round, and ſo uſed as one ſingle Leaver, the *Hypomochlion*, *Fulcrum*, or Prop, being always at the Axis of the Cylinder, or at the Center 𝔄; the longer Arm *d a*, or 𝔇 𝔄; the ſhorter one *a e*, or 𝔄 𝔈, being the Semidiameter of the Cylinder, from whoſe Extremity 𝔈, or the Periphery which it deſcribes, the Weight to be rais'd is continually ſuppoſed to hang; and when it is in this Force, it repreſents that Engine which is commonly call'd the Windlaſs.

The Peritrochium *defcrib'd.*

For a more particular Defcription of the Axis in *Peritrochio*, to which all thefe Engines belong, it is nothing but a Wheel or Arbor furnifh'd with Handles, (by the *Latin* Writers of Mechanicks call'd *Scytalæ*) which are alfo called Logs or Leavers, as D *d e f g* L *h*, *&c. Fig.* IX. and apply'd to the moveable or turning Axis A B, not differing effentially from the Windlafs, and confequently not from the Multiplied Leaver; for here, alfo, the *Hypomochlion*, or Prop, is the Center of the Cylinder A, or the Axis A B, the Weight being fufpended at D K, which is the fame thing as if it was fufpended in E L.

As to the Proportion to be obferved in the Axis in *Peritrochio*, the learned Dr. *Wallis*, in his Mechanicks, *cap.* 7. *Prop.* 1. fays, *that as the Perimeter of the Axis, to which the Weight to be mov'd is fixt, is to the Perimeter or Circumference of the outer Orb to which the moving Force is apply'd, or as the Diameter or Semidiameter of one, is to the Diameter or Semidiameter of the other; fo* vice versâ, *is the moving Force, to the Weight to be mov'd.* To fpeak more plainly, in the Example that lies before us, let A E be the Axis or Arm to which the Weight to be moved is fixt, which fuppofe one Foot diameter, then confequently the outward Axis or Arm A D is three Feet. Now if the Weight to be rais'd is three Hundred Pounds, the Strength that raifes it at that Diftance, be it either the Weight of a Man, or any other accidental Weight, muft be an Hundred Pounds.

Of the Windbeam.

The Windbeam is nothing elfe but an erect *Peritrochium*, only it has but one tranfverfe Beam, which is made to take out and in at Pleafure, a Hole being made through the Cylinder for that Purpofe; to the two Parts of this Beam D A D, may be apply'd the Force of feveral Men at once, (fee *Fig.* 10.) and is a very well known Engine for raifing Corn to the Tops of Houfes, the taking of Timber out of the Water, and laying it on Wharfs, for raifing of vaft Stones to the Tops of high Buildings, *&c.* The Strength of this Inftrument, as indeed is that of all the reft, is in Proportion to the Weight it is to raife or let down, the Length of the Arm or Radius A D, being alfo in a due (*i. e.* in a triple) Proportion to the Semidiameter of the Axis A B.

The Crane, or Tread-wheel, is another Sort of *Peritrochium*, or Wheel, of a large Cavity, in which a Man at L, *Fig*. XI. is endeavouring to climb upwards; the right Hand turns its Ambit round, and at the ſame time windeth up the Rope E F on a cylinderical Axis, which being more and more ſhortened, and brought over the Wheels F and G, by degrees lifts up the Weight H, which being raiſed to the deſired Height, (to wit, to I) the whole Frame turns about the Center K, (both Ways, to the right Hand, or the left, as Occaſion requires) for the Conveniency of changing the Weight. To eſtimate the Power or Force of this Engine, you are to erect L A perpendicular to the horizontal Semidiameter of the Wheel, making the Proportion thus; as A C is to C B, ſo is the Weight to be rais'd to the moving Force.

The next ſort of Axis in *Peritrochio* I ſhall mention, is a horizontal Wheel, *Fig*. VII. which was heretofore drove by the Walk of an Ox or ſome other Animal, which walks upon the Wheel, at leaſt endeavours to go forwards; and by this its Endeavour or Striving, it drives the Wheel backwards, and ſets the whole Engine to work, which forces up the Water from the Bottoms of the deepeſt Wells, to a great Height, through Tubes that are furniſhed with their Buckets; and of this kind alſo, are ſuch horizontal Wheels as are drove by a running Stream, or the riſing and falling of the Tide. And near unto it are thoſe by which our reverend and ingenious Mr. *Holland* and others draw their Water out of the deepeſt Profundity, only the Horſe goes in the Out-ſide of the Wheel, and the Wheel turns with the Horſe. The moving Force to raiſe this Water, ought to be ſo much the greater, by how much the higher it is to be impell'd or forced up through the Tubes or Pipes from the Bottom of the Well above its Brink, which is ſometimes as high as the uppermoſt Stories of Buildings. Theſe are to be eſtimated alſo, in the ſame Proportion as the Line A C, *Fig*. VII. which reaches from the Foot of the Ox, *&c.* treading on the Wheel, to the Center of the Axis, hath to the Semidiameter of the Axis C B. And to this Place alſo, may be referr'd other ſmall Engines, as Turnſpits, and the like; and to this alſo may be referr'd, the outmoſt Wheels of Water-Wind-Mills, and all other Mills that are work'd by Horſes, as before; which, with their cylinderical Axis's, are nothing but Windlaſſes or Cranes, accommodated to the moving of the reſt of the inner Works, which being turn'd by Horſes, or the Weight of Water falling upon them, or the Force of Water running ſwiftly under them, drive them round, and are by ſo much the more powerful, by how much greater the Semidiameter of the

Wheel,

Wheel, or Length of the Leaver is, in Proportion to the Semidiameter of the Axis. And all thefe kind of Engines are call'd by the general Name of *Budromia*.

Of Cogg-Wheels.

Cogg-Wheels, when accommodated to their Axis, are nothing elfe but Windlaffes, and their Coggs the Leavers or Handles; to which is apply'd a Man's Hand, for the moving Force, (if there be no Water or other Help). The Proportions of Cogg-Wheels to raife, or, in other Words, to overcome the Refiftance of Weight, is alfo as the Semidiameter of the Axis is to the Semidiameter of the Wheel; fo that by the Help of the Cogg-Wheel A D C, *Fig.* XIII, whofe Semidiameter A C is to the Semidiameter of the Axis A C, as four is to one. So that a Man whofe Force is equivalent to an Hundred Pounds, turning the Wheel A by the Handle F, which Handle it felf alfo adds fome Force, but is here to be neglected, will be able to raife four Hundred Pounds. But if to this Wheel be added another indented one G, whofe Semidiameter *a c* to the Semidiameter of the Axis (Allowance being made for Friction) is fuppofed to be as three to one. Thefe, by tripling the former Force, will render them fufficient to fuftain twelve Hundred Pounds; and fo the Wheels being multiplied on, the fame Man, or the fame Strength of Water, or other Force, will be able to raife more and more Weight; of which Multiplication of Forces, which is, as it were, infinite, Specimens enough are to be feen in all Mill and Water-works.

Of the Force of Pullies in the lifting and moving vaft Burdens and Weights.

As the Windlafs, or *Peritrochium*, and the like fort of Cylinders, turning upon their Axis, have been proved in the preceding Chapter to have the Nature and Force of the perpetual Leaver; fo the Pulley, which is a Wheel, not only turning about its Axis, but made fo, that at the fame time it is drawn up by the Rope or Cord that goes round it, may very well be accounted, (according to learned *Dialect*) an *Homodromous*, Leaver, or *Vectis*, as will be very evident, to any one that will but confider it well; for if the Cord which is put over the Wheel A F C, be faftened at one End in D, and the other E, be drawn upwards by fome moving Force, fo that at the fame time a Weight fufpended from the Middle of the Wheel be kept in Equilibrio, it is apparent that the moving Force is apply'd in A by one of the Extreams of the Leaver A C, the other

Extream reſting upon the fixt Rope or Cord D C. And laſtly, 'tis plain, that the Weight F will be ſuſpended from the middle Point B, and conſequently as A C, the Diſtance of the moving Force, is to B C, the Diſtance of the Weight from the ſame, *viz.* as one is to two; ſo reciprocally the Weight to be mov'd or ſuſtain'd F, will be to the Force ſuſtaining it in E, *viz.* as an Hundred Pounds is to fifty.

Now there are two Things, eſpecially, to be taken notice of in relation to the Axis in *Peritrochio*, and the preſent Pulley; the firſt is, that the Center C is the *Hypomochlion*, the Weight to be rais'd hanging from its Periphery, or Circumference; on the contrary, here the Center C ſuſtains the Weight, the *Hypomochlion* being in the Periphery of the Wheel, is in the ſecond Place moveable, together with the Weight, by this Means procuring a Perpetuity of the Action in the *Vectis* A B C, quite after another Manner, with half the Force, which otherwiſe, without this Application, could not be done. Now if this Pulley be fixt from above, it will afford no Help towards the lifting the Weight; for if the Pulley A B D, *Fig.* 6. N° 2. be ſuppos'd to be fixt from above, being only moveable about the Center C, the moving Force at E muſt be equal to the Weight it ſelf; becauſe the *Hypomochlion* in this Caſe, is in the Middle at C, and conſequently the moving Force and Weight is equidiſtant from it, as in the Ballance; which very Thing happens in the Windlaſs, if the Weight A E to be kept or rais'd up, be hanged, not from the Extremity of the Axis B, *Fig.* VII. which is a much leſſer Diſtance, but from the Extremity of the Wheel at the Diſtance A *d*, which is equal to the other A D.

Now, again, in relation to the Pulley G, *Fig.* XV. in its Combination with the lower one A, it is to be noted, that the lower one only has the Ratio of a mechanical Power, by whoſe Mediation it is, that a ſingle Force will be able to ſuſtain a double Weight by the aforeſaid Ratio; but the upper Wheel is of little Uſe, only by its Volubility and Poſition, it facilitates the drawing of the Rope; for ſince the Nail D, which is ſuppoſed to be drove hard into a Wall, and by whoſe Help the Part of the Rope D C ſuſtains or holds up one half of the Weight; juſt as if a Man held it up with his Hand, the moving or ſuſtaining Force E G A, muſt of Neceſſity bear up the other Half.

The laſt Example I ſhall produce under theſe Heads, is an Example of accelerated Motion from the Combination of three or four Pullies, the Invention of the ingenious *P. Bettinus*; by the Help of which, a Bucket, *Fig.* XV. may be brought to the Top of a Well in

in half the Time which the common way requires in doing it. If the Rope or Chain E T, to which the moving Force is apply'd, be not immediately faſtened to the Pail or Bucket, but to the Pulley B A, which, by the Aſſiſtance of the Rope D B A G, faſtened a little above the Well at D, ſuſtains the Bucket ſo that the Water may eaſily enter into it, and be drawn up by it; for while the Center of the Pulley C is raiſed up to *c*, 'tis very evident, that the Bucket G muſt at the ſame time be raiſed through double that Space to *g*, becauſe, ſince the Space E *c* by this Hypotheſis is equal to the Rope A G, and A B, the Pulley doth ſo much ſhorten the Rope in its Aſcent, its other Part D B A being at the ſame time ſo much lengthened; it will neceſſarily follow, that in the Poſition of the Pulley *a c b*, the Rope A G will be quite wound up, and that the Bucket G will be drawn up cloſe to it: But here it is equally manifeſt, that the Strength or Force at E muſt be doubled; for the Pin or Nail D will always reſiſt the drawing Force, as much as the Weight of the Bucket is, which is ſuſpended by it, which therefore does, as it were, draw it downwards with an equal Weight. Nor will it be difficult from the foregoing Author, to underſtand after what Manner (the intermediate Pullies being thus multiplied) a given Weight may be raiſed to any given Height in a given Time: But at preſent this ſhall ſuffice.

Dr. Wallis'*s Account of* Cogg *and* Complicated Wheels.

To finiſh what I have to offer in this preliminary Account of Machines, I ſhall add *Prop*. 3. *cap*. 7. of the learned Doctor's Mechanicks, whom we have Occaſion ſo often to mention, as it will put the Principles of Mechanical Hydraulicks into the propereſt Light of any yet produc'd.

Let the Center or Axis of Motion be C, the Tympan or Wheel C A, which being daſh'd upon with the Current of a River at A, turns the Wheel round; and let there be to the ſame Axis of Motion C, a leſſer cogg'd or tooth'd Wheel C B, which being joined with the former, are mov'd jointly together, as if it were about one common Axletree; and let C B be to C A as *a* is to *b*, or as one to three. The Force then in A, according to *Prop*. 1. of this Chapter, will be, therefore, to B, as *b* is to *a*, or as three to one; and therefore one Ounce in A will equipoiſe three Ounces in B.

Moreover, with the Center or Axis of Motion D, let there be another Wheel D B, ſo dentated or tooth'd, and ſo fitted, that its Teeth may agree with the Teeth of the Wheel C B, and ſo wrought into them, that by their Help the Wheel D B may be turn'd about its

its Center or Axis D, and let them ſo fit, that the Number of Teeth of the Wheel D B be in the ſame Ratio to the Number of the Teeth in the Wheel C B, that is, the Ambit or Circumference of one, be in Proportion to the Ambit or Circumference of the other, and the Radius of one, to the Radius of the other; and let there be about the ſame moving Axletree D, a leſſer Orbit or Wheel D E, which may move jointly about with D B, which ſhall be as a Windlaſs whereon the Rope ſhall be wound, and let the Radius D B be to D E, as *c* is to *b*, ſuppoſe as four to one, the Force therefore in B, will be equal to that in E, in Proportion as *c* to *b*, or as four to one. And therefore a Quarter of a Pound in B, will have the ſame Force as a Pound in E. And, as is juſt now ſhewn, one Ounce in A drives four in B; and therefore the Force of one Ounce in A, will ſuſtain the Weight of a Pound in P, and the ſame Force will move or raiſe it, being never ſo little encreas'd.

But if that Weight does not depend directly from E to P, but remains on an oblique Plane T O in π, that Weight that is in π, will be to that in P, and will ponderate in the ſame Ratio as F I, (a Perpendicular of equal Height) will with T O, ſuppoſe as *c* to *d*, or as three to four. Therefore when the Force in A will draw or drive twelve in P, it will draw ſixteen in π.

And from this Form of all Kinds of Machines, (ſays this learned Author in his Scholium on this Propoſition) it is, that a Judgment may be made how all Sorts of Clockwork and other Inſtruments of this kind, that are compos'd of dentated or (in plain Words) Cogg Wheels, are made, eſpecially that Clock which *Pappus* deſcribes out of *Hero Alexandrinus*, *lib.* 8. *pro.* 10. of his Collection.

And from this it is, amongſt many other Obſervations for common Uſe, that which *Ariſtotle* touches upon in the ninth Queſtion of his Mechanicks, and which I have elſewhere hinted at, that large Wheels, Cylinders, Tympans, Spheres, &c. move with more Eaſe than ſmaller ones, which we often ſee happens in Chariot or Coach Wheels, in Spheres and Cylinders that are uſed on the Ground, in the Pullies or Wheels of the Windlaſs, and the like.

Certainly ſo it is in all Water Engines, where, if they be not too wide, leſs Water and leſs Weight will do than is requir'd to drive lower Wheels, and ſuch Wheels will perform their Office much more regular and better, as all that have been converſant in the Coal-works of *Northumberland*, *Durham*, and other Places, can teſtify; but of that, more in its proper Place.

And here, by the Way, I cannot but obſerve, that wherever your Head can't be made high, and you have not a great Strength of Water,

ter, why this very multiplied Wheel may not ſupply that Defect for if by this little Combination of mechanical Powers, there can be three Times the Weight rais'd or forc'd as can be in a ſimple Engine ; ſuppoſe the Diameter of the firſt Wheel, what additional Strength may not be added by the other, ſo as by a little Water to force it up very high in tuberous Pipes ? But this only *en paſſant.*

To conclude this Account of Mechanicks, and the Neceſſity there is for every one that would inform himſelf well concerning Machines ; I have inſerted what precedes and follows in this Account, as neceſſary to be known concerning Engines and Mill-Wheels in general. What has hitherto been ſet down, having chiefly had relation to the Proportion which the Perimeter of the Axis of the Wheel has to the Perimeter of the extream Orb to which any Force is join'd, or that the Semidiameter of the one has to the Semidiameter of the other, for their better Force in moving great Weights, as alſo, of the Power of Multiplying Wheels to that Purpoſe ; and before I quit this Doctrine of the Rowl or Wheel in the Axis in *Peritrochio*, it may not be improper to ſubjoin ſome Speculations concerning theſe rotund Machines or Inſtruments, that our Calculations on this Head may be the more intelligible, and better underſtood.

The general Obſervation, before-mention'd, and which *Ariſtotle* in the ninth Queſtion of his Mechanicks touches upon ; *that large Wheels, Cylinders, and Spheres, move with more Eaſe than ſmall ones,* is here more particularly handled, and as there will be Occaſion to limit this extenſive Poſition, and to produce it in the beſt Light we can, let us bring it to its firſt Principle, and ſuppoſe that a Cylinder, ſuch as *Ariſtotle* calls the Scytalis, or Rowler, that is us'd in Gardens, or for the ſmoothing of any Piece of rough Ground ; ſuch as is in *Fig.* 1. *Tab. Seq.*

If the Weight and Length of the Cylinder be equal, though the Diameter be more in the one than in the other, it is plain, from every Day's Experience, that you may rowl the larger with more Eaſe than you do the leſſer ; becauſe, in the firſt Place, the Center of the large Cylinder is higher from the Plane of the Earth than the ſmall one is, and conſequently a Man or a Horſe pulls at it with the greater Advantage, the *Vis Motrix* or Strain being nearly horizontal to his Hands. But this, I ſay, is when the two Cylinders are made of different Materials, the one of Wood, and the other of Stone or Lead, of equal Length though of different Diameters. And this is agreeable to what the learned *Wallis, Prop.* 1. *cap.* 7. of his Mechanicks, ſets down ; where, treating of the Axis in *Peritrochio,* from

from which this Figure is taken, it is evident, that the Force of the Pulley is nearly horizontal, at moſt not above five Degrees from it; for if the Rope at P were faſtened, in order to be wound up more towards B, the higher you go, the more Difficulty you would meet with in drawing the Burden N R S on.

And this is farther agreeable to what the aforeſaid learned Gentleman has ſet down in *Prop.* 3. *p.* 627. of the ſame Mechanicks; where he tells us, that if the Axis of a fore Wheel was as high as the Breaſt of a Horſe, the Draught Line, to which the Force is apply'd, would be horizontal, and conſequently the Motion and Thing to be moved direct, becauſe they are level; but that a Coach or Cart muſt aſcend and deſcend great Hills and Mountains, (*Vid. Fig.* 2. T O P) it is neceſſary that the fore Wheel be lower than the hind ones, (which is not ſo much us'd in *Holland* and other level Countries, as in *England*,) for that the Draught ſhould be rather parallel to the Hypothenuſe or Acclivity of the Hill, than to the Horizon; becauſe the Draught of the one is much eaſier than the Draught of the other; but, generally ſpeaking, the Harneſs being ſo much lower than the Breaſt of the Horſe, he may be ſaid not only to draw, but alſo to elevate or lift up the Weight which is behind him. But of this only *en paſſant*, it not being of any great Conſequence in the Demonſtration of what we are upon.

Again, this Difficulty or Diſproportion in Wheels, &c. whether for Water, or heavy Land Carriage, on low Wheels rather than high, is occaſioned, as *Wallis* will have it, from the Friction of the Axis or Axletree in the Box; or, in other Words, the Adheſion of the Iron in the Axletree, to that which is in the Bore or Box, cauſed by the heavy Weight or Burthen that is laid upon it; and this is the Reaſon that *Ariſtotle* aſſigns, (in the 11th Queſtion of his Mechanicks) why Rowls that lie plain on the Ground, can carry greater Weights, (as in the moving of Barns, and other Edifices it is viſible,) than Wheels will; to wit, from the Friction that is in the Axletree; for at the ſame time that the Weight lies upon the whole Cylinder, it there reſts upon ſo ſmall a Part as the Axletree only, which makes the Rotation ſtiff, but in the Rowl it is not ſo.

And of this Opinion alſo, is our oft-quoted *Wallis*, *Prop.* 3. *cap.* 7. p. 625. of his Mechanicks before-mentioned; where, treating of the Axis in *Peritrochio*, he has theſe Words, *Poſitâ nempe eadem utrobique Axis magnitudine, quod frictione oritur impedimentum*, &c. of which a larger Account may be ſeen under the Head of Friction. And this is the Reaſon, ſays he, that the Axletrees and Wheels of Coaches and Waggons, when they are ſmaller, wear out, and re-

quire to be oftener repair'd, than thoſe that are larger, from a Reaſon obvious to the moſt incurious Obſerver; to wit, from the Smallneſs of the Wheel, the Rotation of which is the oftener repeated, and conſequently the Friction and Wear alſo, the Body reſting thereupon being of an equal Weight, though not of an equal Diameter or Bulk; and for that, alſo, as the learned *Wallis* has it in his Account of the Difference of Wheels for Carriage, *Prop.* 3. *cap.* 7. of his *Mechanicis Cognatis*, that the incumbent Weight being greater on the lower Wheel than on the higher, it preſſes the harder upon it; as is demonſtrated in his Treatiſe *de Vecte*, *cap.* 6. where the Leaver being placed on two Fulcrums or Props of unequal Heights, the Preſſure is unequal alſo, preſſing much more on the lower or hinder one, than it does on the fore or higher one. And the ſame ingenious Author adds, that it is not (as may be by ſome ſuppos'd) by the fore Wheels of a Coach or Cart's being lower than the hinder, that is an Advantage to it on account of the Weight puſhing the ſame forwards; but, on the contrary, a Diſadvantage, in cruſhing the fore Wheel, the Uſe of which, by that Lowneſs, is only deſigned for turning the ſhorter upon all Occaſions, and not for the Diſcharge of the ſuperincumbent Weight, or to facilitate its Paſſage forwards.

This, and much more, might be produc'd, to ſhew the Advantage there is in large Wheels more than is in ſmall ones. But, on the other Hand, though this may happen in ſmall Bodies, as Rowlers, &c. yet if we conſider the Reſiſtance of Air, it is evident, that the greater Circumference a Wheel is of, ſo much the larger Portion of Air it has to contend with, and conſequently the greater is the Friction or Reſiſtance that muſt unavoidably ſtop, at leaſt much hinder the Rotation of the Wheel, and muſt be the Occaſion that large Wheels move with much more Difficulty on that Account, than ſmall ones do; and this, amongſt many other Reaſons, ſeems to be one, why they have chang'd ſo many large Wheels as they have, in the Cloathing Mills about *Boking* and *Braintree* in *Eſſex*, for thoſe that are of a leſs Diameter. But this is of no great Account.

And, after all the Reaſonings that may be on this Subject, (according to the Theorems and Experiments touching the *Vectis* or Leaver) certain it is, that a large Wheel will lift up a great deal more Water than a ſmall one; becauſe, it is plain, in the Caſe of the *Vectis* or Leaver, which is the Original of all Machines, the farther you place your *Vis Motrix*, or moving Force, from the Center, by ſo much the more is your Power encreas'd which is to raiſe any Body, whether a Fluid or a Solid; though it may true, that little

Wheels

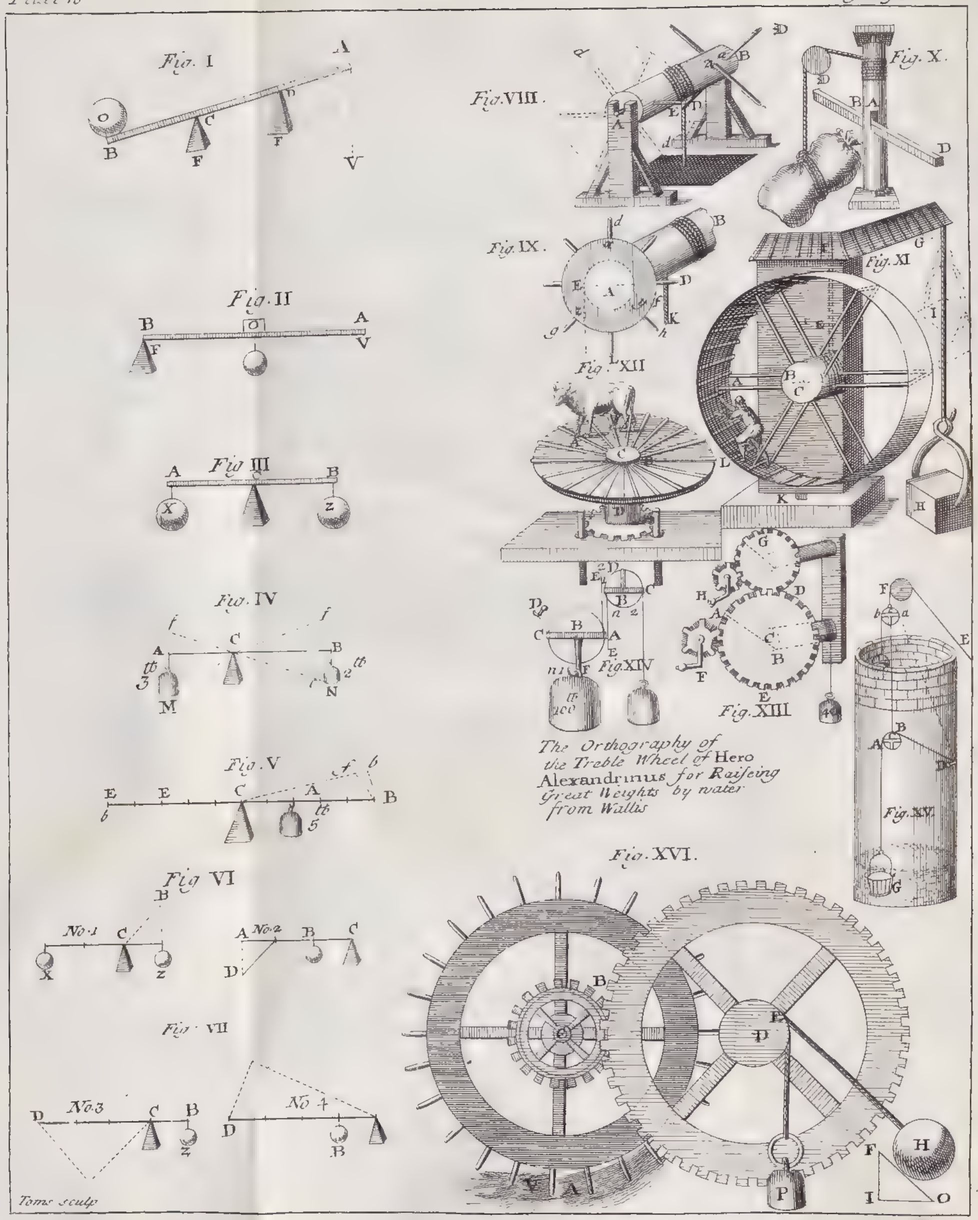
Fig. I
Fig. II
Fig. III
Fig. IV
Fig. V
Fig VI
No. 1
No. 2
Fig. VII
No. 3
No. 4
Fig. VIII.
Fig. IX.
Fig. X.
Fig. XI
Fig. XII
Fig. XIII
Fig. XIV
Fig. XV
Fig. XVI.
The Orthography of the Treble Wheel of Hero Alexandrinus for Raiseing Great Weights by water from Wallis
Toms sculp

Wheels that are broad, may, by the impulſive Force of Water, effect the ſame Things as larger Wheels that are narrower.

Again, in relation to Wheels, and their different Sizes and Poſitions, it is very certain, overſhot ones are the beſt, eſpecially where there is but little Water to drive them; for, as has been elſewhere obſerved, in the Crane, or Tread-wheel. See one of the Figures in the foregoing Table, where a Man is endeavouring to climb up, if his Weight were at A, inſtead of *a*, and touch'd the Orbit of the tangent Line directly, rather than obliquely, the Wheel would move with the more Velocity, and conſequently elevate the more Weight, by how much more the Water, or any impelling Force, falls into the Top of the Wheel at C, where, by undoubted Experiments, it has ſix Times the Force, and will conſequently raiſe ſix Times the Weight, or, in other plainer Words, a ſixth Part of the Water will drive an overſhot Mill, as will drive an underſhot one; and the true Reaſon why there are not more overſhot Wheels, is, that in moſt Places, eſpecially in flattiſh Meadows, the Mill-Pond, or Head of Water, cannot be well rais'd above four or five Feet high, at moſt; and as in thoſe Places likewiſe, there are great Quantities of Water, (even to a Superfluity) there the great Waſte of Water can't be diſcern'd, which it otherwiſe would, were it to depend on a ſmall Rivulet or Spring. No overſhot Wheel ought to be leſs than from ſix or ſeven Feet Diameter, to eight, ten, or twelve; though as to Mines, eſpecially at *Lumley*-Caſtle in the Biſhoprick of *Durham*, there is one of twenty eight Feet. And this naturally leads me to what I have been all along aiming at.

CHAP.

CHAP. XXII.

Of the Siphon, *and other Artificial Fountains and Jets of* Water.

THE Siphon was undoubtedly the chief Inſtrument known in the firſt Ages of the World (beſides the Draw-Well) for the raiſing of Water: And ſo great was the Veneration and Eſteem they had for that Inſtrument, that the *Platonick* Philoſophers (as I find it in *Bockler*) aſſerted, that the Soul ſhould partake of the Joys of Heaven as thro' a Siphon. But this (ſays he) was rather parabolically, than really ſpoken. And *Theophraſtus*, an eminent Phyſician of Antiquity, ſays, that the Marrow being thus drawn up thro' the Bones, cauſes, as it were, a kind of Corruption of that moiſt and vegetative Matter which is inherent in its Nature. From whence *Collumella*, a noted Philoſopher and Gardener amongſt the Ancients, aſſerts, that Vegetables draw their Nouriſhment thro' the Stalks and Stems of Shrubs, as it were through a Siphon, and that this Proceſs is underſtood to be effected rather directly than obliquely; for when the Sun, by its long Heat, has drawn up a great deal of Moiſture, leſt there ſhould remain any vacuate Space within the Cavity or Siphon of the Stem, the remaining Part of the Water is turn'd into Air.

To this Purpoſe alſo Mr. *Bradley*, in his *New Improvements in Planting and Gardening*, has a very pretty Conceit.

But not to detain my Reader any longer. The induſtrious *Ozanam*, in his *Curſus Mathematicus*, Chap. 7. Plate 13. gives an Account of ſeveral Engines whereby Water is to be rais'd, ſuch as the Windmill, the Limace or Screw of *Archimedes*, and others, which I ſhall exhibit in their proper Places. And the firſt Machine I ſhall begin with, is this Siphon; the Effects whereof are ſo well deſcrib'd by the learned *Graveſande*, Cap. 16. Book 2. of his Elements of Natural Philoſophy.

Experiment 1. *Figure* 3. *Tab. Seq.*

LET (ſays he) one End *a* of the Curve Tube *a s b* be immerg'd into Water, whilſt the other End *b* deſcends below the Surface of the Water. If by Sucking, or any other Way the Air be taken out of this Tube, the Water will run thro' *b*, and this Inſtrument we call a Siphon.

THIS Effect ariſes from the Preſſure of the Air that drives on the Water, which is in the Siphon by its Weight on the Surface thereof in the Veſſel. The Air alſo preſſes on the Water that goes out of the Orifice *b*, and ſuſtains it. Theſe Preſſures are equal, and act contrariwiſe in the upper Part of the Siphon, without a Force equal to the Weight of the Atmoſphere (as has been elſewhere declar'd) taking away the Weight of the Pillars of Water, which are ſuſtain'd by this Preſſure.

THE Pillar of Water in the Leg *s b* is longer than the oppoſite Pillar of Water; therefore the like Preſſure of Air is more diminiſh'd on the Side *b s*, and the oppoſite Preſſure overcoming it, the Water flows towards *b*.

Experim. 2. *Fig.* 4.

THE Siphon abovemention'd has this Inconveniency, that if it once ceaſeth to work, the Water will not run again, unleſs the Air be drawn out of the Tube again afreſh. But this may be corrected by making a Siphon, as in the Figure *a s b*, whoſe Legs are equal and turn'd up again; for if the Siphon be fill'd with Water, and one Leg be immers'd therein, ſo that the Surface of the Water may be above the Orifice, then the Water will run thro' the other Leg, for the Reaſon given in the Explication of the former Experiment; ſince the Legs are return'd upwards, the Siphon will not be empty'd when the running out of the Water ceaſes, and ſo the Siphon being once fill'd, is always ready to work its Effect; the Water running forwards and backwards thro' it, according as it is higher on the one Side than on the other.

*Vide Fig.*5. *Tab. Seq.*] Upon the ſame Principles, as the aforegoing Machines, is contriv'd the Siphon for raiſing Water into a Ciſtern. The Effect of which is ſeen by the help of a Machine made up of two hollow Glaſs Balls H and I, which are join'd together by the Tube C D E, the Ball I communicates with the Water to be rais'd up by the means of the Tube A B, which comes up almoſt to the

top

top of the Ball; to the Ball H at the lower part, is join'd the Tube F G, as long as the whole Tube A B.

The Ball H muſt be fill'd without Water thro' a Hole by a Funnel, and then the Hole muſt be ſhut up cloſe. And in ſuch Machines as are apply'd to uſe for raiſing Water out of a Reſervoir that contains it, the Water is brought into the Veſſel H, and the Communication between the Veſſel and the Reſervoir is ſhut up with a Cock.

Experiment 3.] Opening the Cock G, the Water will run out that Way, and the Water will aſcend thro' the Tube A B, up into the Veſſel I; which being fill'd, the Water is ſuffer'd to run away to the Place where you would have it, and by repeating the Operation, the Elevation of the Water continues.

Opening the Cock G, the Air preſſes againſt the Water going out of the Tube F G; the Air alſo preſſes upon the Water in the Reſervoir, and ſuſtains that which is in the Tube A B. Theſe Preſſures are equal, and if you take from the Columns of Water which they ſuſtain, you will have the Forces by which they act upon the Air contain'd in the upper part of the Veſſels, and the Tube C D E, the Pillar F G, becauſe there is ſuperadded to it the Height of the Water in the Veſſel H, does always overcome the Column in the Tube A B, as being longer; therefore the Preſſure at G is leſs diminiſh'd than the other, and ſo is overcome by it, and therefore the Water muſt riſe in the Tube A B, and deſcend down F G.

Of the Limace *or* Screw-Engine.

This Engine was, as ſome ſay, firſt invented by *Archimedes* (though *Vitruvius*, who gives an Account of it, does not mention the Author) for the Benefit of the *Egyptians* when they were overflow'd by the River *Nilus*, and is amongſt the Number of thoſe that are mention'd in the beginning of this Account of ancient Engines.

The *Hollanders* have long ago (as ſome Books, that I have ſeen of theirs of Fortification, intimate) us'd them in draining their moraſſy and fenny Ground; from whence they have been brought into *England*, and us'd in the Fenns of *Lincolnſhire*, *Cambridgeſhire*, and other low Countries, eſpecially in the clearing of their Dykes, and to make room for their Labourers to work. It is of admirable Uſe in drawing the Water out of Fiſh-Ponds, where there is little or no Current, in order to the taking out the Fiſh and cleanſing the ſame. And in *Oxfordſhire*, as is elſewhere intimated, they uſe them in watering their Meadows, where the Level or Courſe of their Rivers lie too low to float them by Nature.

Fig. 1. in the next Table but one, there is a Cutt of that Engine, the Deſcription of which take as follows. In the firſt Place there is a Rafter 10, 12, 14, 16, 18 or 20 Foot long, as you have Occaſion to elevate your Water, though the latter require Horſes to work them, but the firſt may be wrought by Men. This Rafter or Piece of Wood may be alſo from 10, 12, 14, 16, 18 or 20 Inches Diameter, according to the Length, allowing an Inch in Diameter to a Foot in Length, and it muſt be made round, only about a Foot and a Half is to be ſquare at Top, on which is fix'd a Trundle Wheel.

At each End of this Rafter or Wheel-tree is an Axis or Gudgeon of Iron as the Mill-wheel has, for the Engine to turn upon; then within three Quarters of the lower End there is a Regal or Groove, which muſt be made in the Wheel-tree half an Inch deep, to fix the Boards in, and carried ſpiral in the Manner of a Skrew (which, as *Vitruvius* mentions, ſhould be made the Rectangle of *Pythagoras*) or like a winding Pair of Stairs, for ſo it will appear; next you muſt take deal Boards, they being the lighteſt, 18 Inches long; the one End of them is to be fix'd in the Groove, with Pitch and Taw, to prevent the Water getting in between, and then this ſeeming Stair-Caſe is to be cover'd over with Deal Boards, which are to be pitch'd or painted, and the Skrew or Stair-Caſe is alſo to be groov'd into thoſe Boards, about half an Inch deep, and the Joints pitch'd as before, and after that cover'd with Iron Hoops, ſet at every two or three Foot aſſunder, which makes it appear like a long Cylinder or Barrel.

Those of the ſmalleſt Kind that are work'd by Men have only an Iron Handle, as a Grinding-ſtone has, but the largeſt that are wrought by Horſes have a Wheel like the Cogg-wheel of a Horſe-mill, only the Coggs ſtand downwards; and it is drawn by one, two, or three Horſes, as there is Occaſion, Planks being plac'd for them to go upon.

The Bottom of this Engine is plac'd in the Water, the nether Gudgeon running in a Piece of Timber plac'd for that Purpoſe in the Water, the Engine lying ſideways; the upper Gudgeon is likewiſe plac'd in the Engine very truly; ſo that the Cogg-wheel may turn about the Engine, and at the upper End of the Barrel of this Engine is generally plac'd a Trough to receive the Water, as it comes out of the Skrew, and to convey it away into ſome Ditch.

This Engine, which takes Hold of the Water, as a Cork-Skrew does a Cork, will throw up Water as faſt as an overſhot-Mill, whereby in a ſhort Time an infinite Number of Water may be thrown up; and I remember when the Foundation of the ſtately Bridge of *Blenheim* was laid, we had ſome of them us'd with great Succeſs; and they are alſo us'd in the new River Works about *Newbury Berkſhire*, and ſaid to be the Contrivance of a common Soldier, who brought the Invention out of *Flanders*.

CHAP. XXIII.

Of the Antlia or Pump; its Deſcription, Uſes and Kinds, &c.

THE Antlia or Pump was, as *Vitruvius* and *Hero Alexandrinus* informs us, the Invention of *Cteſibius* a Barber's Son of *Alexandria*; and therefore in Compliment to him for this, his ſo uſeful a Machine is by *Wallis* and others ſtill call'd the *Cteſibian* Pump, though made different Ways.

Vitruvius, *Lib.* 10. *Cap.* 2. gives an Account of this Machine, which, as is elſewhere intimated, was firſt uſed for the playing of Organs, and other Inſtruments of Muſick, of which *de Caus* the famous *French* Engineer has given us ſeveral Deſigns, which I ſhall exhibit in their proper Places: But this Pump, as deſcrib'd by *Vitruvius*, does not appear to be the ſame that *Wallis* and others give us; this being effected by Preſſure, and thoſe that they deſcribe by Suction, or rather the Pulſion of exterior Air gravitating upon the Water, when the Air is drawn out of the Tube by the Piſton.

The induſtrious *Ozanan*, *Book 3d. Page* 178. of his Mechanicks, has given a particular Account of theſe two Kinds of Pumps, and of the Manner by which they work their Effects; the firſt he calls a force Pump, which ſeems to be the ſame which was us'd by its firſt Inventor *Cteſibius* above-mention'd, for the playing of Muſick.

The

The *Second* Kind of Pump he calls a *ſucking Pump*, which is effected by the Preſſure of the Air, after the Piſton is rais'd, which ſucks out the Air that is therein, and gives Liberty for the Water to aſcend and fill that Place, contrary to the Motion of a Vacuum.

And, *Laſtly*, he calls ſuch a Pump as raiſes Water, by puſhing it upwards, a *lifting Pump*; but of this and the Effects, and different Manner of working of theſe Pumps, I ſhall write more in its proper Place, and with the learned *Graveſande*, &c.

Monsieur *Ozanan*, who is one of the firſt and chief amongſt the Mathematicians, who in his *Curſus mathematicus*, Page 180. Fig. 143. has treated of Pump Works, in treating of Crank Work, obſerves that the Force of Rivers is commonly made Uſe of to play Engines of this Kind, when compounded into Crank or other Work, by Means of a Wheel, as A. *Fig.* 2. of the next Table but one, whoſe Floats, dipping in the Water, are puſh'd by the Force of the ſaid Water, ſo as to cauſe the Wheel to turn, which turns the bended Piece of Iron or double Crank B C D, which bearing upon the fix'd Points E F, and turning upon them ſucceſſively, comes nearer to, or goes farther off from the Holes I K of the two Barrels I L, K *m*, and ſo raiſes and ſinks the Piſtons, one after another, by Means of their Rods, B, G, C, H, which are faſt'ned to the double Crank, B C D at the Points B C; ſo that the whole Force of the Engine, which, as hereafter will be more amply ſhewn, uniting together, drives up at Bottom, and obliges it to go up into one Pipe, which is common to both Piſtons; the Motion and Aſcent of Water thro' the aſcending Pipe, (tho' not ſo uniform and regular as when there are three or more Piſtons, as is often done in Leaver Work) nearly continual, and without Interruption, the two Cranks forcing alternately, and ſucceeding each other's Stroke.

The Proportion for the Strength and Depth of ſuch Cranks is according to the Strength of your Wheel, which depends on the Height and Cylinderical Weight of Water, that ſuch an Engine is to force up, which is by ſo much the more, in as much as the Stroke or Force, and conſequently the Weight of Water is double of what any ſingle Engine or Pump ſuſtains and forces.

And with the learned *Graveſande*, to render the Effect of theſe common Pumps the more viſible, let there be a little Pump made of Glaſs, in the following Manner, A B *Fig.* 3. *Tab. ſeq.* muſt be a *Cylinder* of Glaſs, about an Inch and a Half Diameter;

in the Bottom of it join a Tube of any Length, as C D; Let the upper Part of it be ſhut by a leaden Ball, ſo that the Water may not be able to aſcend out of the Cylinder, but may eaſily riſe in to it, by raiſing up the Ball which is here made uſe of inſtead of a Valve; the Piſton is mov'd in the Cylinder A B, which, being ſurrounded with Leather, exactly fits its Cavity; there's a Hole likewiſe in the Piſton, which is likewiſe ſtopt with a Ball of Lead, inſtead of a Valve, ſo that the Water may riſe, but not deſcend through the Piſton.

In the next Place, you are to puſh down the Piſton to the Bottom, and to pour Water into it, to hinder the Paſſage of the Air; if the End of the Tube C D be immers'd into Water, and the Piſton be rais'd, the Water will aſcend up into the Cylinder A B, from which it cannot deſcend; wherefore it comes up through the Piſton, when it is puſh'd down; and if you riſe the Piſton again, the Cylinder is again fill'd with other Water, and the firſt Water is rais'd up into the Wooden Cylinder, which is join'd to the Glaſs one, from which it runs through the Tube G.

But ſince the Effect of all theſe Kinds of Machines depends upon the Preſſure of the Atmoſphere, the Water will not riſe above 32, 33, or 34 Foot at moſt.

But to ſhew the Nature of this external Preſſure of Air, and the Effect it has on artificial Fountains, the ſaid ingenious Author has produc'd one from *Hero*, (*a*) the Conſtruction and Effect of which take as follows.

Let *Fig.* 4. *Tab. ſeq.* be two equal Elliptical Veſſels A B, and C D, exactly ſhut on all Sides, and made of any Sort of Metal.

In each of them there is a Separation paſſing through the Center of the Ellipſis, which divides the whole Veſſel into two equal Parts.

The Separation *m n i* in the Veſſel D C, is perpendicular to the Axis of the Ellipſis, the Separation *c f g h* of the other Veſſel muſt be inclin'd to that Axis.

There is a Brim made about the upper Part of the Veſſel A C B, to make a Baſon.

Four Tubes are join'd to theſe Veſſels, the *Firſt*, *o p* go through the Cavity B of the Veſſel A B, without having any Communication with it, and deſcends almoſt to the Bottom of the Cavity D, and aſcends to the upper Part of the Cavity B, but not quite ſo high as to touch the upper Plate of it. The *Third q r* reaches from the lower Part of the Cavity B, almoſt

to

to the Bottom of the Cavity C; the *Fourth* X *n* is made faſt to the upper Part of the Cavity C, and reaches almoſt to the upper Part of the Cavity A.

Laſtly, There is a Tube *z y*, which going through the upper Plate, is ſolder'd to it, and reaches down ſo deep in the Cavity A, that its End *z* is but a little Way off the Bottom.

There are Cocks join'd to every one of theſe Cavities, or elſe they have other Holes that are ſhut up with Screws that have Leather on them; the chief Uſe of them is to let out the Water very clean from the Cavities, leſt they ſhould grow ruſty when the Machine is not in Uſe.

To come to the Experiment of this artificial Fountain, pour in Water thro' the Tube *o p*, ſo as to fill the Cavity D; and if you continue to pour in Water, it will riſe up through the Tube *s t*, and then deſcend through *q r* into the Cavity C, which is alſo fill'd, the Air aſcending through X *u*, and going through *z y*.

Turn the Machine upſide down, opening the Cocks of the Cavity C and D, the Water will deſcend into the Cavities B and A: Having again ſhut the Cocks, as alſo the Hole *y* of the Tube *z y*, ſet the Machine again the right Side upwards, and pour Water in again through the Tube *o p*, till the upper Surface of the Machine be cover'd with Water. Now, if the Hole *y* be opened, the Water will ſpout up to almoſt twice the Height of the Machine, and the Motion of the Water will continue till the Cavity A be emptied with its Water; the Heighth of the Spouting-water will continually diminiſh, and at laſt it will be double the Diſtance of the Veſſels.

The Effect of this Machine is to be attributed to the Compreſſion of the Air in the Veſſels; the Preſſure of the Atmoſphere at *o* and *y*, as alſo in the Veſſels is equal, but their Preſſures deſtroy one another, and therefore are not to be conſidered in the Examination of this Machine: When at laſt the Water is pour'd into the Tube *o p*, it is ſuſtain'd in it by the Preſſure of the Air contain'd in the Cavity D, and acting upon the Surface of the Water, which ſtands at a ſmall Height in that Cavity; which Air therefore is compreſs'd by the Weight of the Water, whoſe Height is *p o*; we ſpeak of the Preſſure, by which the Preſſure of the Atmoſphere is overcome.

The Air in the upper Part of the Cavity B, communicates with the Air abovemention'd, by the Tube *s t*, and is equally compreſs'd, and acts with the ſame Force, upon the Surface of the

the Water in that Cavity: This Preffure is to be added to the Preffure arifing from the Height of the Water, in order to have the Force by which the Air is comprefs'd in the Cavity C, as alfo the upper Part of the Cavity A, by Reafon of the Communication through the Tube X *u*; the Preffure therefore upon the Surface of the Water in that Cavity A, is equal to a Pillar of Water, whofe Height is double the Height of the whole Machine; and therefore it fpouts up, as if it was prefs'd by fuch a whole Column; that is, to a Height not much wanting from the Height of that whole Column.

THIS Height is continually diminifh'd, for the Columns of Water which comprefs the Air become fhorter and fhorter, becaufe the Water afcends in the Cavities C and D; and its Height is diminifh'd in the Cavity B, at the fame Time that the Cavity is continually evacuated, and the Water afcends through a greater Space, before it comes to Y; therefore it is driven to a lefs Height than Y.

AND thus much of the Defcription and Theory of this ufeful Inftrument: Let us now enquire what is proper to fet down, as to its Ufes, and the feveral Kinds of them.

MONSIEUR *Ozanan* informs us, That Sir *Samuel Moreland* was the firft who brought this Pump to any Degree of Perfection with us; which I take from that *French* Author, having taken great Pains to find out what Sir *Samuel* has left on that Head to no Purpofe: But as *Ozanan* tells us, it was at that Time an Invention which he valued very much; let me explain it in his own Words, and make Ufe of the fame Drafts he has given it us in; N O R is the Profile of the Pump, (*vid. Fig.* 10. *Tab. feq.*) the Sucker which is at the Bottom of the Pump L N the Pifton, which muft be a Cylinder of Brafs, exactly turn'd in the Lathe, made to rife and fall in the Midft of the Cylinder of Water, contain'd in the Barrel of the Pump, in fuch a Manner, that it rubs againft nothing but a fmall Circle of Leather, well prepar'd and fix'd into a little Hollow at the Top of the Pump, on the infide over againft O N. Through this Leather the Pifton goes up and down, with the greateft Eafe imaginable, and without any confiderable Friction; for this Friction and Wear has been fuch, that I have known in Pumps (the Cylinder of which has been of Lead) that the Sucker has foon, (by the Imperpendicularity of the Stroke of the Pifton, if I may fo call it) wore away the Sides of the Pump, and render'd it ineffectual.

To bring this Engine to Perfection, that ingenious Gentleman aſſures us, coſt him twelve Years Study, and a great deal of Money; and without this new Invention, it would have been impoſſible to have reduc'd the raiſing of Water to Weight and Meaſure, as he had done: A D L is the Rod of the Piſton, upon which are ſlipt Weights, which are between E F and G H, to counterpoiſe the Water which is rais'd, and to keep the Piſton upright between the two Pulleys B and C; V I is the leaden Pipe in which the Water riſes, after it has paſs'd through the Sucket I, which hinders it from falling back into the Barrel of the Pump; and this ſeems to be the beſt Method and Foundation for ſingle Forces, and from which we may form any Compound Engine, though the Pullies may be omitted in all Crank or Leaver Work, *&c.*

The ſingle Piſton for Pump-work being thus eſtabliſhd, we come now to take a View of what may be ſaid as to Valves, Clacks, *&c.*

All Valves, (as Monſieur *Ozanan* has it) are not made the ſame Way, which is the Reaſon they have different Names; for when a Valve is flat like a Board, it is call'd a Clack, and when it is round, and goes ſomething tapering (which is by much the beſt, inſomuch as the Air and Water in their Paſſage upwards has more Power in a hollow Concave, than it has on a flat one, to raiſe the ſame) it is call'd a Sucker; and theſe are the moſt in Uſe (eſpecially in *France*) when they have a Tail which comes perpendicular out of the Middle of their Convexity, which Tail by its Weight draws down the Convex Part, to make it ſtop up cloſe round the Hole, through which the Water paſſes, lifting up the Valve when the Piſton is rais'd.

These Valves are uſeful to ſtop the Water in a Pump, keeping it from coming back again, when once it has been rais'd by Means of the Piſton C D (*Fig.* 5. *Tab. ſeq.*) which muſt move up and down freely in the Barrel A B, and at the ſame Time exactly fill it, that the Air may not paſs between, when the Piſton is drawn up; and then when the ſaid Piſton is rais'd, ſince Air can't ſucceed in the Place of it, the Clack F will riſe, and give Way for the Water to paſs through the Hole, which it ſtop'd before; and on the contrary, when you puſh down the Piſton C D, and preſs the Water which has been rais'd, the Clack F ſhuts; and ſince the Water can't get out that Way, it is forc'd out through the Pipe G H I, which communicates with the Body of the Pump; however, as the learned and laborious *Deſaguiliers*, in his Notes on *Ozanan* (from whence this Account is chiefly extracted) has

it,

it, this Pump would be imperfect, if there were not a Valve ſomewhere in G H I, ſuppoſe a little above H, to prevent the Water from deſcending, in Caſe of the Failure of a freſh Succeſſion, which is often the Caſe.

Of Pumps, they are generally divided into two Kinds, the one is known by the Name of the ſucking Pump, or Pump wrought by Suction, and the other a forcing Pump, which is effected by the Preſſure of the Piſton, or Piſtons (for in compound Engines there are ſometimes two, three, or four working in different Barrels, to cauſe a perpetual Aſcent of Water) continually preſſing upon the Water, and forcing it through a Pipe fix'd into the Side of the Pump, as was in the laſt Paragraph explain'd.

The firſt of theſe two Pumps, and which is much of the ſame Nature as that deſcrib'd by *Wallis*, and inſerted in the laſt Chapter, is properly a ſucking Pump, becauſe it draws the Water through its own Trunk, where the Piſton or Rod goes down; and of one of theſe Kinds, I have ſeen one, at a Perſon's whoſe Memory I ſhall always ſpeak of with Honour, the late General *Webb*'s, that drew Water near 80 Foot deep, that is, 25 Foot to the Clack at the Bottom of the Barrel, and the Rod or Piſton about 55.

The *French*, as alſo we and other Countries, cauſe a Hole to be made through ſuch a Piſton, from Bottom to Top, even from D to F, where they place a Clack, that when the Water is riſen, by the raiſing the Piſton (which in ſuch a Pump is called a Bucket, done round with us with Leather, as has been before intimated) it may ſtill riſe higher when the Bucket is puſh'd down; for it will preſs upon the Water under it, which will puſh up the Clack F, and run up through the Bucket; and this Clack will immediately ſhut again, upon the raiſing of the Bucket, becauſe the Water will preſs upon it, and then open as the Piſton is ſunk to make a ſecond Quantity of Water (to ſucceed the firſt) and to enter into the Body of the Pump (which will at length, and in great Heights, and after many Strokes) be fill'd up to the End A, where the Water will run out: But to effect this the quicker and better, and to ſet the Pump at Work immediately, Men generally fill the Barrel with Water; and it muſt be noted, that the Valve or Clack below ought to ſhut cloſe, to keep the Water from deſcending down, becauſe ſometimes the Pump may not be uſed for two or three Days, and it will be neceſſary to have it always full.

To proceed, that the Valve F (*vid. Fig.* 5. *Tab. ſeq.*) may play freely, the Rod E C of the Bucket muſt be faſtned to it by Means of a bended Piece of Iron, as I C H, ſtrongly fix'd to the Bucket; and it muſt be noted, that in this and all other Pumps, whether ſimple, or compound, that in caſe the Water lies low, you may make the Tube E G, which goes into Water 24 or 25 Foot long at leaſt, for ſo high will the external Preſſure of the Atmoſphere raiſe the Water of its own Accord; *Gallileo* and others have indeed ſet down, that the Weight of Air will raiſe it 32 or 33 Foot high, or ſometimes higher; but as that Air does not always act with an equal Power, but that Water riſes and ſinks as the Barometer does, ſometimes higher, and ſometimes lower; and as the Springs very often riſe and fall, ſo that the Tube may not imbibe any Water at all, at leaſt not enough for the Supply of this and other Pumps in the Summer Seaſon 24 or 25 Foot above the uſual Surface of the Water will do; and it is adviſable alſo, to have a ſquare, wooden, or leaden Box, with Holes in it, to prevent the Pebles coming into it, laid 5 or 6 Foot lower than the uſual Surface of the ſaid Water is; but if it be not above 8 or 10, or any ſuch like Quantity of Feet to the Water, then you may place the Bottom of the Barrel and Clack where you pleaſe.

This Pump is alſo call'd a lifting Pump, becauſe it raiſes Water by puſhing it upwards: Let A B be the Body of the Pump divided into two Parts A K, B I, of which B I muſt be in the Water, as alſo the Bucket or Piſton C D, which moves upwards in this Part B I, by Means of the Rod F G, fix'd to the Point F, round which it moves together with the Piſton C D, and its Rod E C, by Means of the Rod G H, *Fig.* 8. *Tab. ſeq.*

The Rod E C of the Piſton C D muſt be a Pipe continued in C D quite to D, (*vid. Fig.* 8. *Tab. ſeq.*) where it muſt have a Valve, and there muſt be alſo one at O; for if you puſh downwards, the Rod G H to make the Piſton C D deſcend, the Piſton preſſing upon the Water, will force it into the Pipe E C, which will open the Valve at D, ſo that the Water may paſs above it; then the Weight of the Water will preſs down the Valve, and hinder it from going back the ſame Way that it came: So when the Piſton C D is rais'd, it will preſs the Water above it, and cauſe it to riſe (by lifting up the Clack O) and go into the Part A K, where by its Weight it will preſs down the Clack O, and remain where it is: Thus will A K be fill'd by Degrees, till at laſt the Water runs out at the upper End A.

By Means of this Pump, you may raiſe Water to a conſiderable Height; but it has one Inconveniency which attends it, and that is, that as the Rod F G muſt be always in the Water, which if it happens to be out of Order, it is hard to mend it: Beſides, ſince the Rod F G moves circularly about the Point F, the Piſton C D cannot riſe or fall perpendicularly: For this Reaſon, the following Pump, which is rather to be recommended, ought to take Place, having nothing troubleſome in it, but the Length of its Rod.

Let A B for Example be the Body of the Pump, which is to ſtand in Water as far as G H, and let the Piſton C D have a Hole through it from D to F, where there muſt be a Clack to open when you puſh down the Piſton C D, after you have rais'd it, to make the Water come in through the Clack E, which opens when you raiſe the Piſton, and ſhuts when you puſh it down, to raiſe the Clack at F, which will give Paſſage to the Water, and then ſhut it ſelf, as ſoon as you raiſe again the Piſton C D; and the Clack E will open again at the ſame Time, and give Paſſage to the Water, which will afterwards be made to riſe through the Clack F, by ſinking the Piſton as before: Thus continuing to raiſe and ſink the Piſton, the Barrel will be fill'd with Water, which will at length run out at the upper End at A.

Thus much of the ſucking and lifting Pump, with the Improvements to be made to it: The ſecond, and indeed the chief Pump now remaining, is the Force Pump, ſo called, for that it does, by the Strength and Force of the Piſton, drive up the Water with great Strength to any Height required, when to the Rod C E is applied a Power as great as the Reſiſtance, or, in other Words, ſtrong enough to raiſe the Cylinderical Weight of Water, which is in the Pipe H I; and if there be a Clack at I to open and give Paſſage to the Water, when it riſes through H I to enter into the Pipe I K, in which it will remain, becauſe its Weight keeps down the Clack I, which muſt riſe again, and give Paſſage to a freſh Quantity of Water, which will riſe through the ſaid Pipe H I, when the Piſton C D is preſs'd down; thus by raiſing and ſinking this Piſton, the Water will continue to aſcend in the Pipe I K, until it goes out at the End K.

And this Kind of Pump (eſpecially when it is compounded of other Powers of equal Strength and Force, as ſhall be hereafter taught) is of the greateſt Uſe, by forcing of Water out of

the deepeſt Profundity, from whence the Ancients could not poſſibly raiſe it, by any Art they had.

Having thus taken a View of the Theory of the Antlia or Pump, and its Parts, let us now proceed to the Practice of it, as it is ſet down by *Wallis*, and others.

And the firſt Pump I ſhall give an Account of, is the Antlia, or ſo much fam'd Pump of *Cteſibius*, as we have it from *Wallis*, *Prop.* XV. *Cap.* XIV. of his Mechanicks, though it ſeems to be ſomewhat different from the Machine, ſo call'd by *Vitruvius*, *Lib.* 10. *Cap.* 2. as before hinted at.

This uſeful Inſtrument, (*vid. Fig.* 1. *Tab. ſeq.*) is made of a long Piece of Wood (or of more, if there be Occaſion) cut out in the Inſide of a Hollow Cylinderick Manner, and put down into a hollow Pit or Pond, the upper Part ſtanding out of the Water, and the lower Part within the Surface of the ſaid Pond or Pit; of which Water is to be underſtood, that it is not free from the Preſſure of the Air, but by its Gravity and Elaſticity ſubject to it.

Somewhere in the Hollow of the Pump, let there be a croſs Bar fix'd, in the Middle of which is the Hole D, through which the Water aſcends; and upon this Hole is a Valve or Cover E, ſo fix'd, as that it will open or ſhut, according as it is preſs'd from above or below: Alſo let there be a Sucket let down from the Handle above, ſo fitted to the Sides of the hollow Cylinder, that the inſinuating Air can't poſſibly paſs by the Sides of it, which Sucket or Sucker has likewiſe a Hole F in the Middle of the Trunk, and fitted in the ſame Manner, with a Valve or Clack at G, as E was at D.

These Things being ſo fix'd, whilſt the Sucker is drawn up and down by the Motion of the Handle; and when the incumbent Air, by which the Water that is under it is preſs'd into the Hollow of the Pump through E and D, and through the Valve opening at E, even to the Bottom of the Sucker, but not higher than C I, which is the greateſt Altitude of the Equilibrium; and being free from the Preſſure that is above, and drove on by that which is below, and *è contra*, whilſt the Sucker is depreſt again by the Motion of the Handle.

It preſſes alſo the Water that is under, that it may aſcend through D; for the Valve at E being ſhut by this Depreſſion, that at G is open'd, through which the Water (having overtopt the Sucker) is retracted again, and then it is, that the Work is to be repeated; and the Water having found its Way through

the opening at H, it there flows out, being ſucceeded again by Water riſing again through D, in the Place of the retracted Sucker, and that continually.

But if the Altitude C D be greater, or if indeed it be not leſſer than C I, in *Fig.* 1. which Ballance we ſuppoſe comes to paſs by the Preſſure of external Air, the Water can't aſcend through D, nor can the Water at C be preſs'd any farther, than the other Parts A C B, and ſo the whole Labour of the Engine would be loſt; but if D be under I, the Water will aſcend through D to I, if it is not hindred, even to the Bottom of the Suckers, unleſs it be higher than I; but if the Sucker be drawn up again, ſo as that F or G overtop the Altitude I, the Sucker having left the Bottom, the Water will remain at I, in ſuch a Manner, that if the Sucker ſhould draw the Water, which was before at I, through F G, the Valve G being ſhut, it will lift up this alſo, and pour it out through H.

From thence it is (ſays a learned Author) that Quick-ſilver, and the Reaſon holds good in other Liquids, can't be rais'd by a Siphon, Syringe, or Pump, above 29 or 30 Inches, nor Water above 33 or 34 Foot, and all other Fluids, according to the Ratio or Proportion of their reſpective Gravities; the Cauſe being the ſame in all, namely, that all thoſe Things which ſeem'd heretofore to be done by Suction, are truly done by Pulſion, ſuppoſe by the Air, or any other Preſſure; and that there is nothing done by the Sucker, but drawing out the Air, to make Room for the Reception of whatever ſhall aſcend by that Preſſure.

We have already noted, in *Lib.* 2. *Cap.* 10. of this Syſtem, this great Miſtake that *Wallis*, and after him the Reverend Dr. *Wells* and others have labour'd, when they have imagin'd, or indeed have rather directly ſet it down as their Opinions, that Water could not be rais'd by a Siphon, Syringe, Pump, or any other Inſtrument of that Kind, above 33 or 34 Foot high, when it is notoriouſly known, that Water is and may be rais'd, even by a ſingle Pump, above 100 Foot, and by Chain-work, &c. from the Depth of 200 or 300, as whoever will take the Pains, may ſee in the fine Buildings and Gardens of the honourable *George Doddington* Eſq; one of the Lords of his Majeſty's Treaſury.

On this Account it is, that I have exhibited the Profile or Section of this Pump, *Fig.* 1. *Tab. ſeq.* where the inſide Part is open, and where the exact Manner of working it may be diſcover'd, ſtill allowing what the learned *Wallis* and his Followers have

have ſaid, that Water will not by any natural Means, or in other Words, will not, by the Laws of Hydroſtaticks, riſe above 33 or 34 Foot, or ſcarce to that always, unleſs it be forc'd by the continual and repeated Motion of the Piſton in the Pump to aſcend.

It has been alſo obſerv'd already, as will be often repeated, that Pump-makers generally fix their Clack or Valve D, at about 25 Foot above the Surface of the Water, eſteeming that the greateſt Height, to which the Water will riſe well, by the Preſſure of the Atmoſphere; at leaſt they do ſo for Fear that the Water ſhould ſink at any dry Seaſon, (as it often does, 2, 3, 4, or 5 Feet lower than it is uſual) and then the Pump will be in Danger of being made uſeleſs.

The ſame Members are made uſe of to compoſe this Pump, as are for Pumps of any Kind; but becauſe the Sucker D, which is made of Braſs juſt ſo, as to fit the Cylinder of Wood, Lead, *&c.* in which it works, muſt be always in the Water; it is neceſſary, that the ſaid Sucker have a large Hollow in the Middle, and have a Clack at Top as G, through which the aſcending Water may paſs, when the Rod or Piſton, with the Sucker, is deſcending; which Clack or Valve will immediately, in its Aſcent, lift up the Water higher and higher, till by the Repetition of the Stroke, the Water is aſcended to its intended Height at H or I, which may be either more or leſs, as the Length of the Rod (to which the Sucket or Sucker, and which is alſo ſometimes call'd the Bucket) is.

It may be thought, that this Bucket or Sucker, working always in Water, may go very heavy, and that it won't be in the Power of a ſingle Man to work it; but we have already demonſtrated, that we don't feel the Weight of any Bucket, and the Water which is in it, when we draw, till it begins to riſe out of the Water, becauſe the Water in the Bucket, or that which riſes by it, is of the ſame ſpecifick Gravity with the reſt of the Water; and tho' this Bucket or Sucker be of Braſs, yet as it is very hollow, and not large, the Difference from an *Equilibrium* is but little; and as the Bucket or Sucker is hollow on the inſide, by the opening of the Valve or Clack therein, upon Depreſſion, the Valve or Clack at FG, is ſhut, and the Water forced to aſcend, contrary to its own Nature, to the greateſt Height.

To conclude what we have to ſay on this Head, if theſe Things can be effected by a ſucking Pump, with much greater Eaſe

Eaſe will it be done in a forcing Pump, as deſcrib'd in the Beginning of this Chapter, where the Stroke of the Piſton is ſo great, that by a double, treble, or quadruple Repetition, as is in all compounded Engines, the Water may not only be throw'd one, but even 200, 300, or 400 Foot high, as will be more particularly ſeen, when we come to treat of compound Engines.

It is obſervable in one of the Pumps before deſcrib'd, the ſquare Leads, that Sir *Samuel Moreland* preſcribes for to hang on the Rod or Piſton, can't be us'd; becauſe, as the Piſton works always in Water, they will hinder the Aſcent of it up, unleſs they are hollow in the Inſide; however, to keep the Piſton ſteadily perpendicular, the two Wheels may be made Uſe of that are at the Top. I have alſo added a new Sort of Handle, which makes the Pump go ſo eaſy, as that tho' you draw the Water three or fourſcore Foot deep, yet a Child of 10 or 12 Years old may work it; beſides which the Piſton will move thereby more perpendicular, and with more Eaſe between the two Wheels, than without them; and all that I have to add is, that you load the Bucket or Sucker with Lead, or other Weights, ſo much as that it may deſcend in the Water with Pleaſure; it being certain, that in this Sort of Pump it is much harder to depreſs than raiſe the Piſton. But to come to a more particular Explanation of this Pump, the Valve D is ſuppos'd to be 25 Foot above the Surface of the Water, in the Well or Pond, which will riſe by the Preſſure of the Atmoſphere, to that Height; and over the Hole D there is a Valve, E ſo plac'd acroſs, as to open or ſhut, according as it is preſs'd from above or below; as alſo a Bucket, at F G, let down from above by the Rod or Handle (ſo fitted to the Sides of the hollow Cylinder, as that the Air can have no Paſſage between) which alſo hath a Hole in the Middle of its Bottom, and a Valve at G fitted to it, as hath D E. Things being thus ordered, while by moving the Handle the Bucket is drawn up (the Air being upon it, and by that Means there will be a leſs Preſſure of Air upon the Water below the Bucket) the Water in the Well being preſs'd by the ambient Air, will be forc'd up into the Hollow of the Pump, through the Hole D (as was mention'd in the laſt Kind of Pump) opening the Valve E, as far as the Bottom of the Bucket, provided it be not higher than I, the Top of the *Equilibrium*, as being free from any Preſſure from above, and thruſt up from below; but on the contrary, by turning the Handle the other Way, the Bucket is preſs'd down, and preſſes the Water

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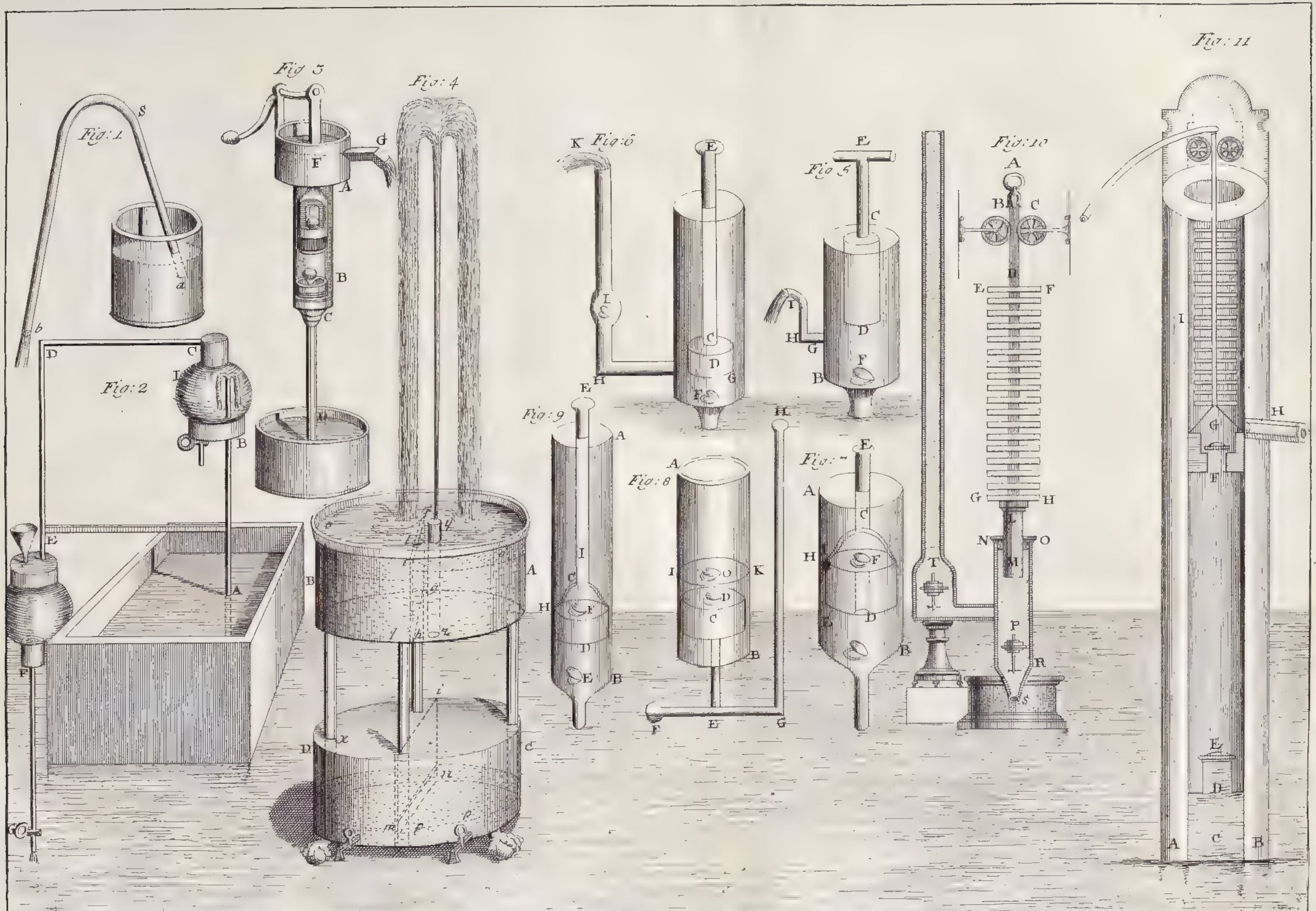
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Fig: 10
Fig: 11

immediately under it, which aſcends through G D. By this Depreſſion E is ſhut, and G opened, through which the Water having got above the Bucket, is drawn up with it; and when it is drawn back (the Valve G being ſhut) and finding Paſſage, flows out at H, which, as will appear by the Figure, is much higher than the Bucket; and that conſequently all the Piſton and Bucket muſt work always in Water, which in the preceding Figure it is not ſuppoſed to do it there, raiſing the Water no higher than H, tho' this raiſes it to L or M, as there is Occaſion: The Bucket of the other does indeed work in the Water; but then its Stroke is but ſhort, and the Rod is but juſt immers'd, the ſquare Pieces of Lead hindering its Aſcent any higher.

As to the Handle, juſt above, O in the Pillar of the Pump, is a Pin, on which the Handle P is fix'd, which moving the Arm Q, which is fix'd to the other Handle R, by Rivets at *a* and *b*, the upper Handle or Movement Q is fix'd a Pin at A, where it gives Motion to the Rod or Piſton; and ſo the Bucket G, at the Top of which there is a Valve that opens and ſhuts. Note, There are Holes at *f h*, to which you may remove the Arm Q, as you ſee Occaſion.

This Surface of the Water is ſuppos'd to be from C D to G F, to the Height of the Atmoſphere, when Allowance is made for the ſinking of Water in dry Weather; and that it may ſpring out haſtily there, even 25 Foot above the ſaid Surface, as has been before noted; and this Kind of Pump is by ſome called the Atmoſphere Pump.

By Means of the Spout L, you may pump up Water into a Ciſtern 7 or 8 Foot above the Ground, and the Rod S may be 40, 50, 60, even to 100 Foot long.

Thus much of the ſingle common Pump; all that I have to add to it is, That this new invented Handle, which I think makes it go much eaſier than the common Way, is to be ſeen at my very good Friend's, *Borlace Webb* Eſq. at *Biddeſden Wilts*, where they draw their Water above 80 Foot deep, by the Help of this Handle only, and that with one ſingle Perſon.

But as theſe Pumps are made different Ways, and are ſometimes double, treble, and quadruple, I ſhall, in the Courſe of the enſuing Treatiſe, ſet down ſome of the beſt Sorts I have ſeen or read of; and the firſt is a double Pump, as we have it from *Bockler*, *Page* 35. *Fig.* 143. (*vid. Fig.* 2. *Tab. ſeq.* of this Book) and which I am told the York-buildings Company uſe, (though I have not ſeen it) which for Cheapneſs, and the Quantity of Wa-

ter

ter it will produce, is of moſt excellent Uſe, and is wrought only by two Men.

THE Piſtons E E are let down into, and ſtrictly fix'd in the Concave Tubes D D, and are there mov'd; but ſo that no Air can paſs by the Sides of the Piſtons, into thoſe Tubes; the Croſs-beam Mark B B is alſo faſtned into the Poſt A, and mov'd on a Pin key'd into the Middle thereof, at C, from the Motion of which the Valves or Clacks at F F, open and ſhut, and produce the ſame Effects, as in other Pumps.

THE next Pumps I ſhall produce are taken from an *Italian* Author of great Repute in Machines, the one is a double Pump, drove by a Man going in a Tread-wheel, which giving Motion to the two Cranks G G. by the Rotation of the Axle-tree H F, fixt as they are in the Frame of Wood I. I. gives Motion to the two Piſtons E E, which deſcend alternately, and either lift up the Water by the Means of the Clacks and Valves B C D, the Water entring in at the Arches A. A.

THE chief Things which I have to obſerve from this Draft, is the great Care this *Italian* Author has taken to make theſe two Piſtons fall perpendicularly, by framing them into two ſquare thick Boards at *h. h.* and the Reader will eaſily diſcern, that by Means of the Rings E E, in which the Cranks G G work, are deſign'd to facilitate that perpendicular Stroke; this Figure is ſeen in the following Table.

THE next double Pump I ſhall Figure out and deſcribe, is taken from the ſame Author, where is figur'd a Man ſtanding (at Q Q.) upon a Frame of Wood, and there being a Center at R, whereon there is fix'd a Vectis or Leaver, at each End of which there is a great Weight fix'd, mark'd S. S. which counterpoiſe each other, and are of a Weight ſufficient to force the Water up through the Elm or Lead Pipes A A; ſo that by the alternate Motion of the Man on Q Q, and the Center E, the two Piſtons T T ſucceed each other in Preſſure downwards, and Aſcent upwards, forcing up Water in the Coffer B, where there is Buoy; which Coffer is fix'd on the Frame H, and lies ſloping for the Water to run out, with the greater Pleaſure into the Ciſtern K.

IT appearing by the Draft, that the Water is rais'd but a little Way, I take Notice, that that was an Imperfection in the *Italian* Author's drawing, which I was not willing to alter; but 'tis very certain, that this Pump, be it either us'd by Way of Suction or Preſſure, will raiſe the Water as high, and with as much Eaſe, as any of the Pumps yet mention'd: So that ſuppoſing you allow

D D

J Boyle Delin Toms Sculp

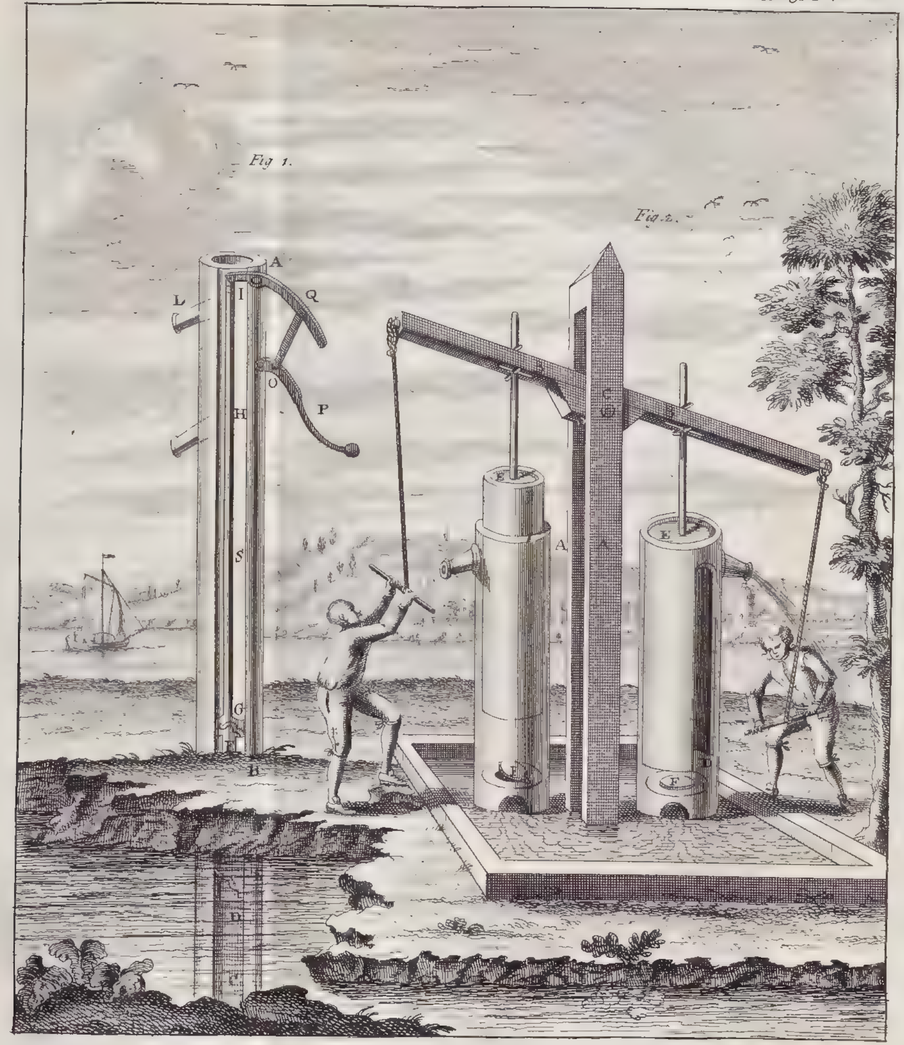
Fig 1.
Fig.2.
A
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Q
L
O
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H
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G
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A
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D

DD to be 25 Foot, the leaſt Height of the Atmoſphere, the Frame H H, on which is fix'd the Coffer B, may be plac'd at any Height you pleaſe, even to 100 Foot, provided the Piſtons T T be of that Length; but then it will be a conſiderable Time at the firſt pumping, before the Water arrive into the Coffer.

I have another Thing alſo to obſerve, which is, that there is at Q Q, and all along the Piece whereon the Man treads, an open Grove for the Piſton T T to work in, which going through the Top of the Coffer at M M, maintains a conſtant perpendicular Stroke, which is what all our Engineers, by Methods ſometimes very ſhocking, endeavour to do, to make the Piſtons fall perpendicularly, and to prevent that Friction, which is almoſt unavoidable, in moſt Kinds of Movements in Pump Work.

I might in this Place have added a great Number of other Kinds of Pumps, which are us'd in *England*; but that I find this Volume is ſwelling beyond its intended Bulk; ſo that I ſhall deſiſt ſaying any more, except I do it in the Notes adjoining to this Book.

CHAP. XXIV.

Of the Chain-Pump.

I Might, from *Bockler* and others, have produc'd almoſt an infinite Number of Drafts of Engines, which are plac'd under the Terms of *Budromia, Hydrotechnema*, &c. the firſt ſignifying the Methods of raiſing Water by Buckets, and the other by Globes, or Figures of any other regular Shape, fix'd to a Rope, which Rope being faſtned at each End, and paſſing through an Elm or other Pipe, which reaches from the Bottom of a Well to the Height to which the Water is to be convey'd, brings up the Water along with it; but theſe Kinds of Engines being out of Date, I ſhall paſs over them, and confine my ſelf to two Sorts of Engines only, which are reducible to this Head; the firſt is the Chain Pump of *De Caus*, from which it may be ſuppoſed, the Reverend Mr.

Holland firſt took his Model. And the laſt is a Chain Bucket Pump, the excellent Invention of a poor honeſt Countryman of our own, I mean Mr. *George Gerves*, whoſe Engine I think very juſtly excels any Thing of this Kind ever yet invented.

THE Deſcription of the firſt Pump is found in the *Engliſh* Edition of *De Caus*'s *forcible Movements*, *Page* 34. *Fig.* 26. What he recommends in it to be of great Advantage, is, that the Forces riſe and fall perpendicularly in their Barrels. It is (ſays he) eaſy to comprehend by the Figure (*vide Plate* 16. *Page* 316.) that there are four Places in the Arbor, which are hollowed or channell'd, and in the Half of the Channels there are Pinns A E, encountering with Pinns which are in P H, which make them to aſcend and deſcend, and in deſcending, they raiſe one without hindering the other, or being hindred by any other Pinns, which are in the Roll mark'd P H, becauſe they paſs by the void Place of the Channel, or rather Collar mark'd D D, C C, by Means of the Chain and Pully K K: And ſo they riſe and fall each in his Turn, and force the Water with great Violence to fifty or ſixty Foot, and ſome to one, two, or three Hundred, as Occaſion requires; and this Machine may be made to go, either by a Horſe or Horſes, or by Water; but being heavy, requires a great Force to be applied to it.

I have ſeen that of the Honourable *George Dodington* Eſq. at *Gunville*, *Dorſet*; as alſo that of his Grace the Duke of *Queensberry*, at *Amesbury*, *Wilts*, with Works of the ſame Kind at other Places; but there is ſuch a vaſt Quantity of Timber Work, and the Machine goes ſo very heavy, is ſo noiſy, and ſo apt to be out of Order, that I thought it not proper to make any more Obſervations about it.

THERE are of theſe Chain Pumps in the curious Collection of the Right Honourable the Earl of *Iſlay*, that have 6 or 8 Piſtons to an Engine, but four is I think generally ſufficient, which is all I have to add to this Engine. The laſt Rope or Chain-Engine I am to mention in courſe, is that lately invented by Mr. *George Gerves*, at Sir *John Cheſter*'s at *Chichley* in *Buckinghamſhire*, which for its Curiouſneſs and Uſes, and going with leſs Water, is allow'd to exceed any Machine *yet invented. Vide Plate* 17. *Page* 316.

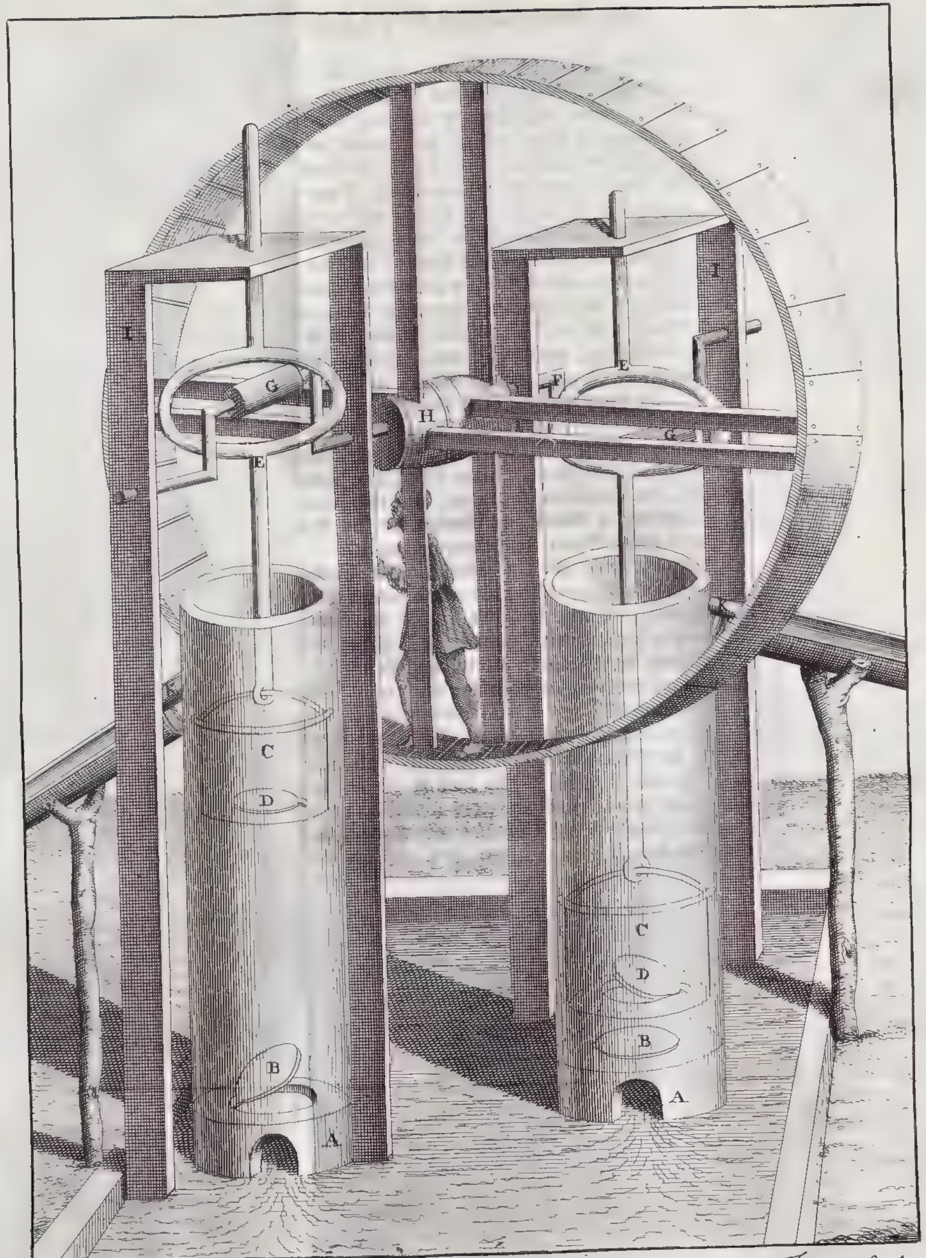
I ſhall not take upon me to give a particular Deſcription of this Engine, tho' I have had it ſeveral Times in my Hands; becauſe I am unwilling to anticipate the Account of it, juſt now a publiſhing by the Inventor himſelf.

IN general, it is, and may be called *a multiplying Wheel Bucket Engine*, which moves continually by a ſmall Fall of Water, without the Help of any Man, Water, Wheel, Wind, or Fire,

purely

Pa: 314

Plate 14



Toms Sculp

I have not had Time to make any particular Computations of the Quantities of Water this Machine will raiſe, tho' it is plain by Inſpection, that not above two Thirds of the Water at moſt runs to Waſte, and that if there be an half Inch Pipe of Water running from the Conduit A, yet the Machine will be always in Action; only whilſt the two Buckets are filling, it ſtands ſtill; and one may dare to challenge any Engine or Machine that was ever made, to go with ſo little Water as that of two Thirds of an half Inch Pipe, ſince there is no Spring, where or howſoever ſituated, but will work it: And there is this to be ſaid more, that for every Foot Fall you have from the Ciſtern C, to the Waſte B, juſt ſo many times 6 Foot high will it raiſe the Water to the Ciſtern it is to be emptied at, at N. Suppoſing then that in Plate the 17th, the Fall to be 6 Foot, the Water will be rais'd near 30 by this Engine. But a more exact Account will in a little Time be publiſh'd by the ingenious Inventor himſelf.

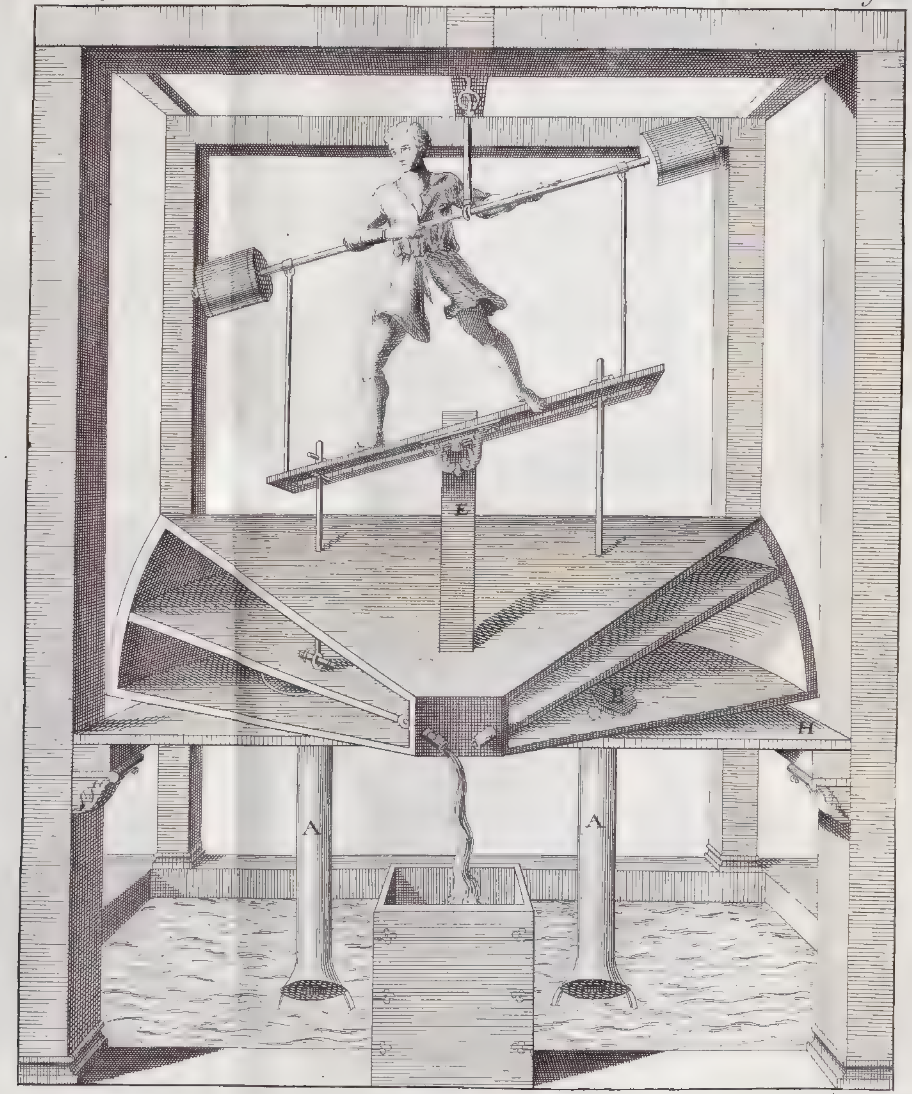
I now go on to Chap. 25. L is the Plan of the Houſe, where the Engine is plac'd, K K is the Roof, R R are Windows lighting the Engine.

CHAP XXV.

Of Crank Work, and of regulating Engines.

WITHOUT Doubt the Uſe of Cranks in all Engines, is of as long a Date, as any Power that belongs to Machines of this Kind, eſpecially double, treble, and quadruple Pumps. *Bockler* in his *Theatro Machinarum*, and a great many other Authors, have given the Profiles and Deſcription of ſeveral Kinds of them, ſome of which I intended to have inſerted in this Place, but that I had not Room, this Volumn beginning to ſwell beyond its firſt Intent. The *Cochlea Quadruplex* that *Bockler* makes mention of *Page* 29. *Fig*. 92. and which, he ſays, is to be found in *Agricola*

de



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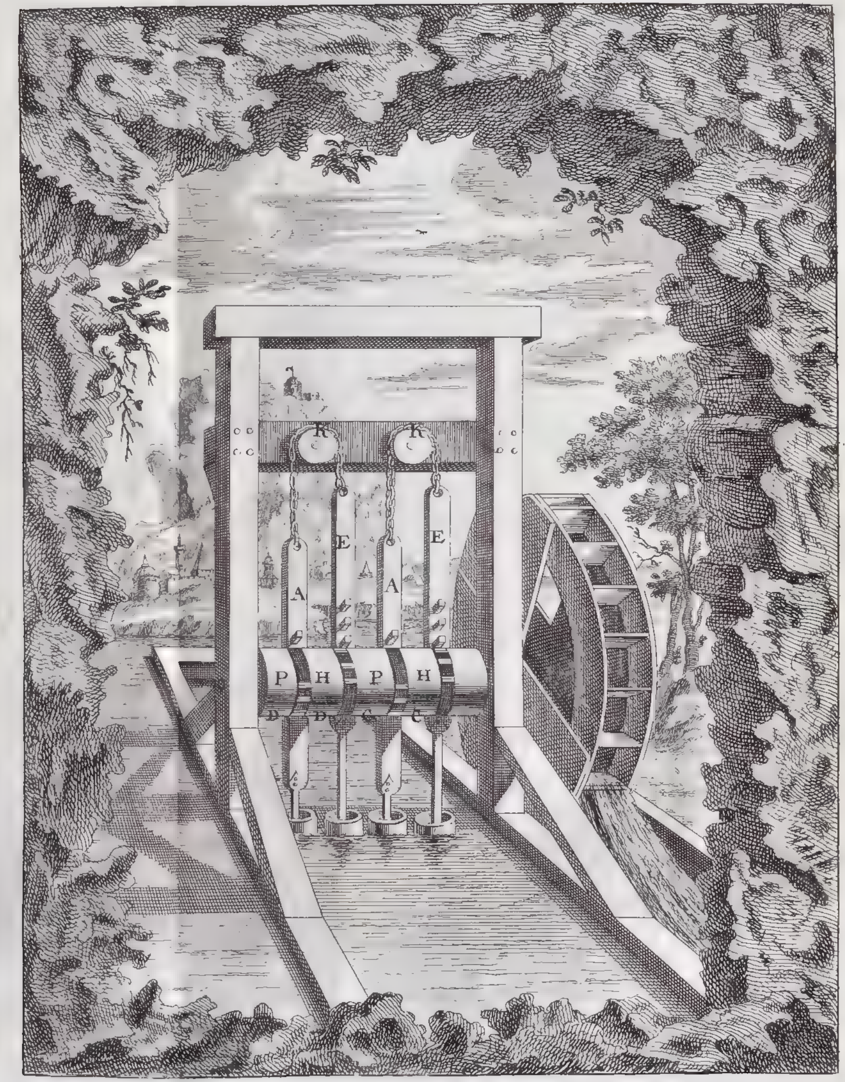
K
K
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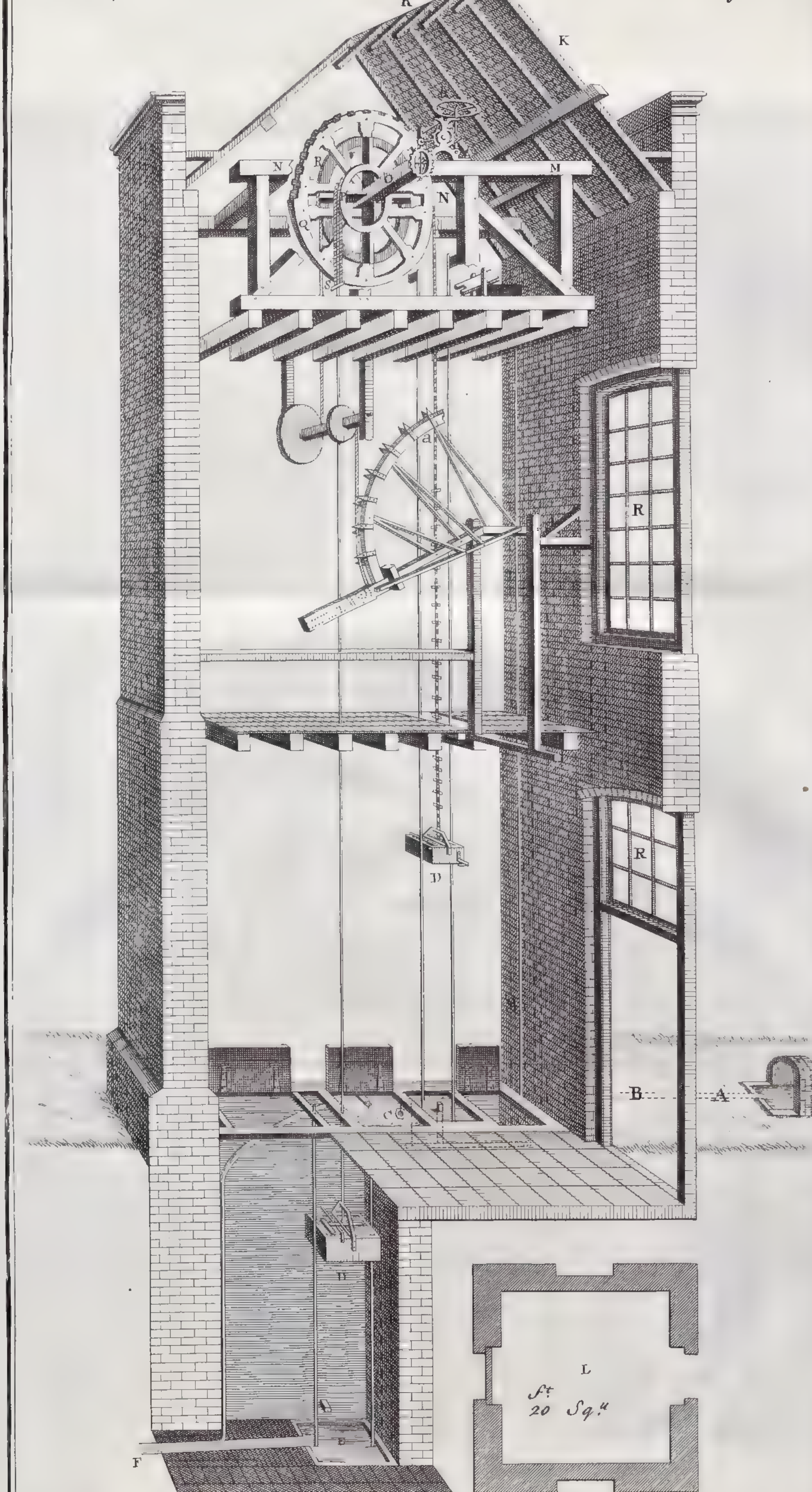
C



H. Beighton F.R.S. delin. Will. Henry Toms Sculp.

Mr. Gerves's Multiplying Wheel Bucket Engine

little Valves before-mention'd, are cover'd, as are ſeen at N (in *Fig.* 1. *Plate* 18.) *Prædict.* and at *No.* 9. *Fig.* 2. is another Valve, to prevent the Water's returning back again, but to cauſe it, by a freſh Acceſſion, to aſcend the large Pipe thro' N° 11.

THE Manner of the Rods being fix'd into the Piſtons *a, a, a,* as mention'd in the laſt Paragraph, is ſeen in *Fig.* 3. *Plate* 18. where *d* is the Rod, and *a* the Joint; which Piſton having a Notch (as from *b* to *c*) the Rod has the Liberty of riſing or falling, as the Aſcent or Deſcent of the Cranks and Regulators force it.

THIS Engine, I ſay, is ſubject to as little Friction, as any Engine of this Kind I have ever ſeen; for whoever will but be at the Pains of coming to ſee the Perpendicular Stroke Forcers we have on this Side the Water, at Mr. *Kent*'s, the great Still-houſe at *Vauxhall*, will ſee how much thoſe Engineers have endeavour'd to defend their Forcers againſt Friction. But of this more hereafter.

CHAP. XXVI.

Of the Crank-Work, vibrating Leaver, and complicated or treble Wheel Engine for raiſing Water.

PLate 19. *Page* 320. is the Plan and Perſpective of the Merchants Water-Work Engine at *Tom*'s Coffee-houſe in St. *Martin*'s *Lane*, which I inſert in this Place, becauſe it is preparatory to the Deſign of the *London Bridge* Engine; which by the Nature of the Work ſeems to be done by one and the ſame Hand, there being only this Difference, that this is an Over-ſhot, and that an Under-ſhot Wheel. *Fig.* 1. is the Plan, whereof A A is the Extremity of the great Wheel turning upon the Axis B B, C is the Spur Wheel turning the Cogg Wheel D, which by its Rotation gives Motion to the Cranks F F F, and they conſequently to the Regulators or Leavers E E, and the three Rods and Piſtons mark'd *g g g*, which turn on the Iron Pins or Axis at *h h*; all which is effected by the Preſſure of that little Water which comes out of the Pipe or Trough at I,

vid.

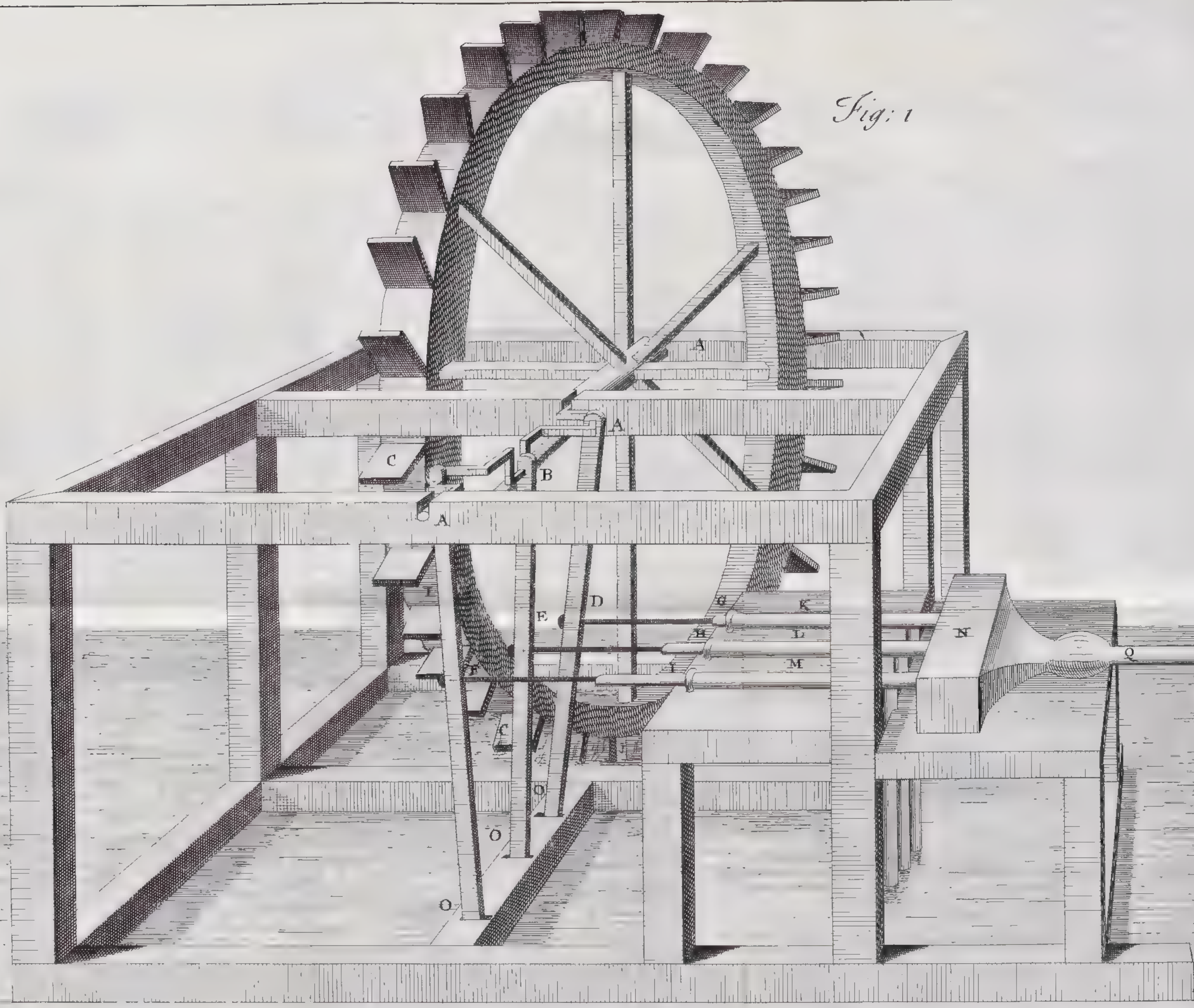


Fig: 1

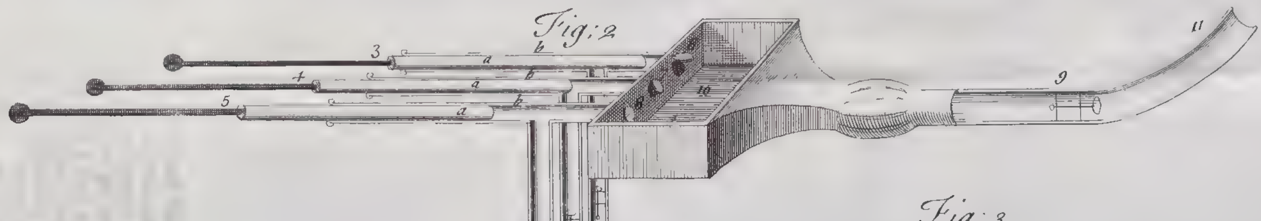


Fig: 2

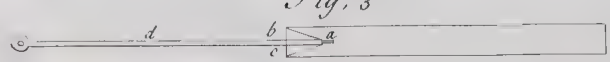


Fig: 3

W. Halfpenny delin. Toms Sculp

of tha

vid. Fig. 2. *Tab. prædict.* where the Fixation of the Leavers is viſibly ſeen to be in the Frame of Wood at K.

The Shape and Poſition of the Wheels are the ſame as in the *London Bridge* Engine, which follows, but the Floats or Boxes are ſet cloſer and nearer together, on Account of the ſmall Quantity of Water which is to drive the Wheel; and here it is viſible, what a ſmall Quantity of Water will drive an Over-ſhot, over what will drive an Under-ſhot Wheel.

There is another Thing which I would obſerve in this Place, and that is as to the Number of Forcers which are needful in an Engine. Doubtleſs when theſe Kinds of Machines were firſt erected, there was but one Forcer, then the Number was augmented to two, and lately they are ſtill encreas'd to three or four, tho' on Account of the Intermiſſion of the Strokes, which, together with the Friction that is in the Pipes, and the Interruption and Interpoſition of the Air, us'd to be the Occaſion that the Water would not (eſpecially in great Lengths) iſſue out of the Ends of the Pipes regularly, but only alternately, and in Gulps.

Whatever the Proportion of theſe Piſtons be, it is generally ſuppoſed by the beſt Workmen, that three Piſtons are ſufficient to maintain a conſtant Stream, tho' in very large Pipes of Conduct, ſuch as thoſe of *London Bridge* are; and where it is requir'd to raiſe a great Quantity of Water, they allow four Piſtons to one Pipe of Conduct.

L L L are the Piſtons, ***m m m*** the Barrels or Pipes where they work, and N N N the Repreſentation of the Clacks or Valves.

N. B. In this Place I muſt remark a Miſtake of the Engraver, who has in *Fig.* 1. *Plate* 19. ſhew'd the Cranks F F F, as if they work'd above the Leavers E E E, when in truth they work under them, as may be ſeen in *Fig.* 2d. and Leavers ***m n o.***

The next Crank Work Engine I ſhall produce, is the Plan and Perſpective of one Part of *London Bridge*, which for Curiouſneſs of Contrivance, the Length of Time it has went, without any other than very neceſſary Repairs, and the great Quantity of Water it throws up towards the Supply of that great Metropolis, may (Allowance being made for the Difference there is in the Number of Piſtons that are in the one and the other) be well a Parallel, if not an Exceeding, to that great Engine of *Marley* itſelf, and which (as it has not as yet been produc'd in publick) will not, I humbly hope, be unacceptable to the judicious Reader, being, as I am told, the Work of one Mr. *Sorocold*, a very good Engineer, in the Reign of King Charles or King *James* the IId. whether he had any Aſſiſtance from

Sir *Samuel Morland*, or any of the Great Men of thoſe Times, I have not been able to learn.

A Deſcription of the Plan, Vid. Plate 20. Page 320.

A A is the Plan of the great Wheel.

B B is the main Axletree on which the Wheel is fram'd, and *l*, *l*, the Spindles, which from the Rotation or Movement of the Wheel give Motion to the Spur Wheels *c c*, and thoſe by the Movement of that to the other 4 Wheels mark'd *x x x x*, which Wheels *x x x x* turn the Cranks *e e e e*, two of which at each Work are going up, whilſt the other are going down; and this gives Motion to the Leavers *f f f f* on each Side the great Wheel, *&c.* and cauſes the Piſtons *g g g g* at each Quarter to have an alternate Aſcent and Deſcent in forcing up the Water thro' the Pipes *i i*, coming out at *h h h h*, and conveying it from thence to a proper *Reſervoir* or *Reſervoirs* for the furniſhing the City.

The Frames of Wood *k k*, &c. are for all the Wheels to turn upon, as *l l l l* before-mention'd, are the Iron Axis's, on which they turn; and here it is remarkable, that the two Wheels *c c*, whether by accidental or natural Contrivance of the Wheel, or by Deſign, is not material; but by Means of it, the Water is thrown over the Wheels *x x x x*, into the Axis or Spindle of the little Wheels, keeping them continually moiſt.

A Deſcription of the Perſpective of the London Bridge *Engine*, Plate 21. Page 320.

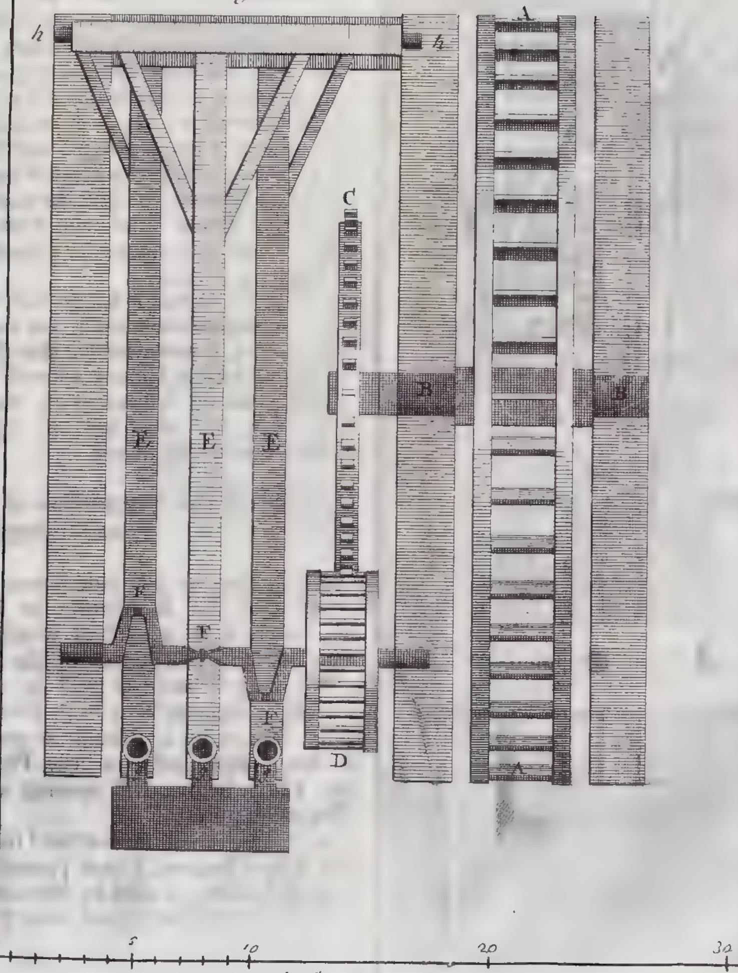
In this Draught, at one Side View, is ſeen the Grand Wheel of the Engine, with the Regulators or Leavers; the firſt is mark'd A. A. the others B B. at each of which are the Regulators or Leavers, which from the Rotation of the Spur Wheels *c c*, give Motion to the Cog-Wheels D D D D, and they again to the Iron Rods, mark'd altogether E at both Ends. By this

F F F F, containing 4 Piſtons at every Quarter, are all moving up and down alternately in the Pipes G G G G, the Suckets, which are a little below, ſtill opening and ſhutting, as the working of the Engine requires.

And with this I ſhall finiſh what I have to ſay as to the complicated treble Wheel Engine; I now proceed to the ſingle Wheel Crank, and vibrating Leaver, as uſed by Mr. *Alderſea* in the Water Works of *Woodſtock*, *Shrewsbury*, and other Places.

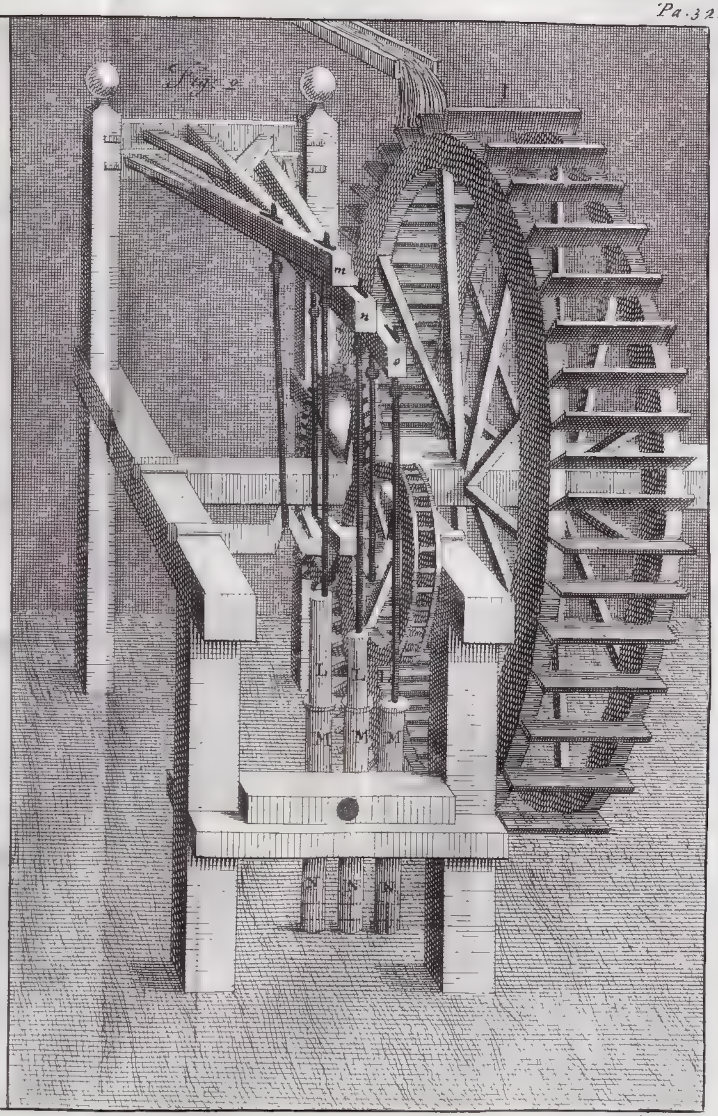
CHAP.

Fig. 1.

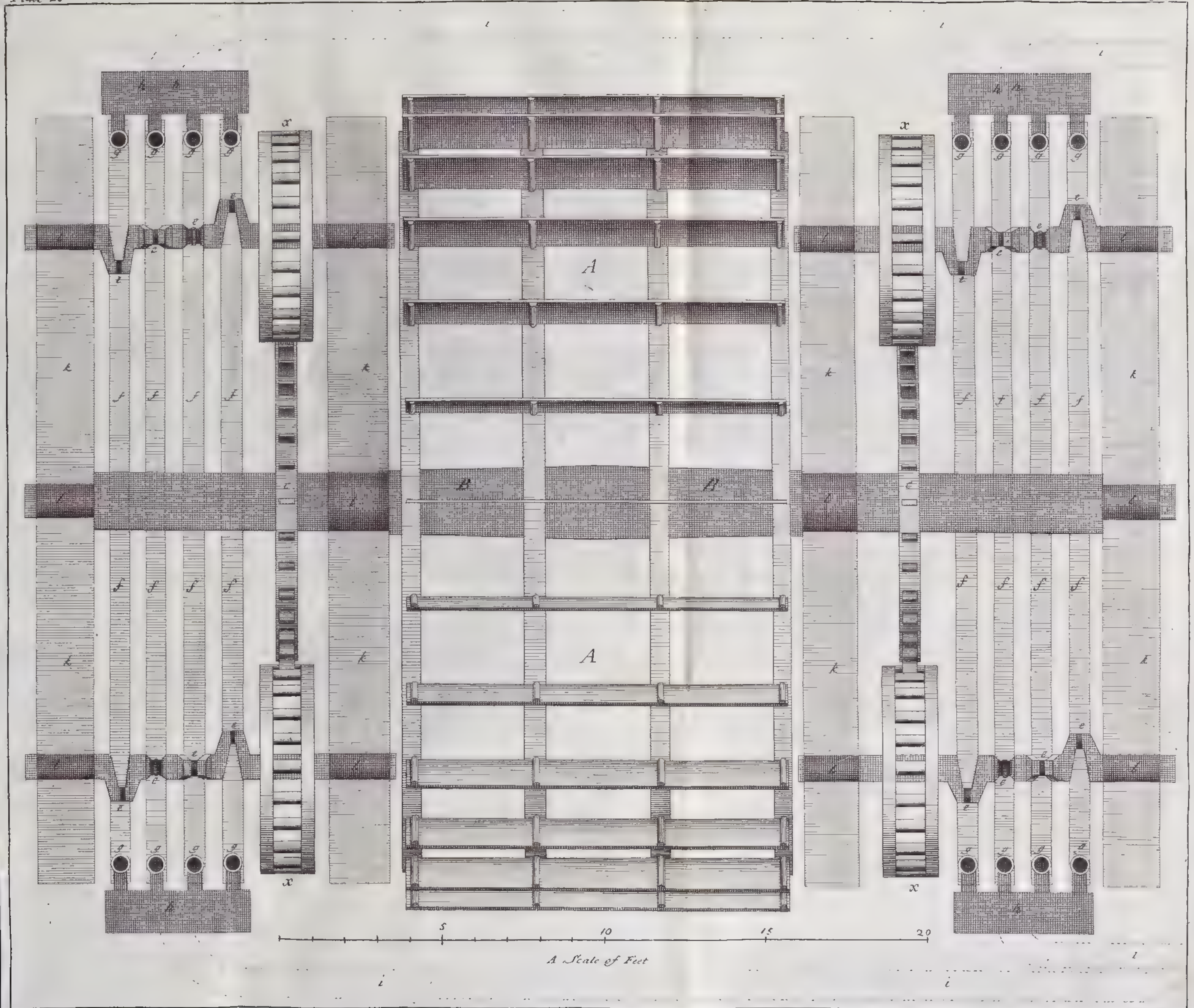


A Scale of Feet

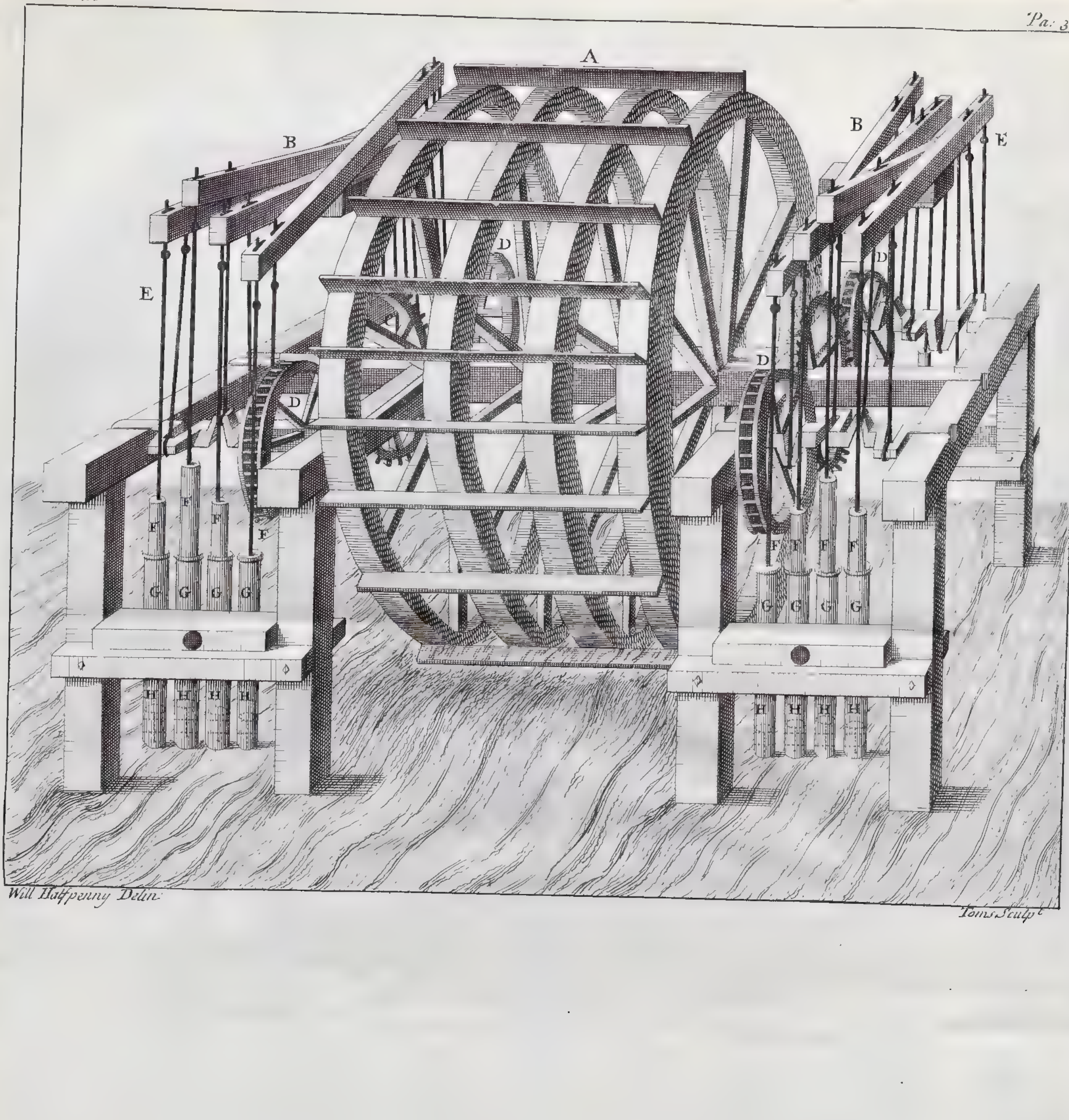
Fig. 2



Toms Sculp



Wm. Halfpenny Delin.



Will Halfpenny Delin.

Toms Sculp.

B B B the Thorough or Trough, which conveys the Water upon the Top of the Wheel C C into ſeveral Boxes, made ſomewhat like a *Roman* Figure of V turn'd a little ſloping, which having puſh'd on the ſaid Wheel, is delivered into a Waſte or Tail Water D D D, which runs thro' one of the ſmall Arches or Bridge next to *Roſamond*'s Bower.

There are but three Cranks on a Side, and the having of double Works (*viz.* three of a Side) is that in Caſe any of the Cranks in one Side are broke, the other may be us'd, which is either faſtned to, or looſen'd from the Wheel by a Collar pull'd off or put on at *f f*.

The little Letters *a a a* *a a a*, are the Keys to the vibrating Leavers, which reſt on the Fulcrum or Prop on which they move by the Rotation of the Wheel C C; which turning the Cranks mark'd Q Q Q, Q Q Q, move the Leavers C C C, &c.

The Piſtons which are thereby agitated, and put into Motion, and which are well known by the Marks O O O O O O on each End, &c. forces the Water out of the Coffer *r r r*, *r r r*, ſituate as they are at each End, from whence paſs Pipes, which are in the Plan unſeen, under one of the Stair-Caſes S S, up thro' the Bridge, to the Ciſtern on the Top of the Offices.

T T T T are Paſſages round, and in the Front of the Engine, to view it and come at it, to keep it clean from the upper Part T 2 T 2, is as high as the Top of the Wheel, which is ſeven Foot and an half Diameter, and is play'd by as little Water as any Engine of this Kind can be; the little Marks *o o o o o o o*, &c. are the Foundations of a Grillade of Iron Work made to keep any Body that aſcends the Stairs, and goes to pull up the Sluice at B from falling upon the Engine; and ſomewhere in the Coffers near Z, are Boy Cocks, being hollow Balls of Copper, which riſe or fall, according as the Water in the Coffers *r r r*, &c. do; ſo that when the Coffers are Brim-full, and like to run over, thoſe Boy Cocks ſhut cloſe, and admit of no more Water to make a Wetneſs or Dirt in the Engine Houſe.

There are Pipes which come from the Stream A, thro' the Wall by B, which ſupply the ſaid Coffers with all common Water: But there was a Deſign, whether perfected or no, I am not certain, to fill one of the Coffers, (*viz.*) that next *x*, with fine Water from *Roſamond*'s Well, which lies within about 100 Yards of that Place.

I have been the more particular in my Account of this Engine, having had the Pleaſure of converſing much with Mr. *Alderſea* the curi-

curious Contriver, and ſhould be ſorry, if from the Length of Time, and the faint Memorandums I now have of this curious Piece, it be not the moſt perfect; tho' I think, and am pretty ſure, that there is nothing very material omitted in it: And in Behalf of the Engine, it may be truly ſaid, tho' perhaps there have been ſeveral Engineers, who have ſince improv'd upon it; yet, as it is the eaſieſt Piece, going (comparatively ſpeaking) with as little Noiſe as a Watch or Clock; ſo Mr. *Alderſea* (tho' he has long left Art behind him) deſerves the juſt Applauſe of all honeſt ingenious Men.

There is one Thing which I ſee liable to an Objection, which is that the Fulcrum or Prop, which is noted by the Marks *a a a*, is not in the Middle of the Leavers, which, if my Memorandums fail me not, is Fact in the Execution of it; but if it be an Error, it is ſuch a one as I could not, during the Hurry of Buſineſs, and little Time, I have had, correct; which is all I have to add in this Place, only that Y Y Y Y, &c. is the Foundation of the Walls encompaſſing the Work.

A Deſcription of the new Part of the Chelſea *Water-Work Engine.* Vide Plate 23. Page 324.

I omit the old Work, becauſe it is ſo near the Model of the Spur and Cog-Wheel at *London Bridge*, and confine my ſelf to one Part only of the New; which was laſt erected, being, as it is ſaid, the Invention of the late ingenious Mr. *Rowley*, and others, and which is made nearly reſembling the little Model, which ſtands in the Houſe firſt erected, only in that there are five Piſtons, and in the erected Work but four.

That the Engineers (whoever they were) proceeded upon the ſame Model as Mr. *Alderſea* did at *Blenheim*, confining themſelves to a ſingle Wheel and Cranks only, I need but juſt repeat; and that this new way of working goes eaſier, and is better at low Water than the old, Experience teaches; for tho' by the Number of Wheels, and the Nature of complicated Work, the old Work goes quicker at high Water than the other, the Rotation of the great Wheel moving the Spur and Cog-Wheel with great Celerity; yet the ſingle Wheel, when unloaded of the Weight of the Tail Water, goes much quicker and eaſier than the other, which is much impeded by the Friction of one Wheel againſt another; an Obſtruction ſo great, that were not the Quantity and Preſſure of the Water almoſt invincible, it would not have its due Effect.

Nevertheless, tho' a great many Arguments may be produc'd for the new way of working, where the Tail of the Wheel is clear'd by a quick Paſſage of the Water from its Tail; yet I can't but ſay, that for an Engine continually working in the Water, as that of *London Bridge* does, the Addition of the Spur and Cog-Wheel is the Beſt for the Reaſons before hinted at. This being premis'd, let the Deſcription of the Engine follow.

A, *Fig.* 1. *Plate* 23. is the Trough from which the Water, by the pulling up a Sluice there, falls under the Paſſage or Gang-way on the Wheel B B B, the waſte Water goes off at C into the River *Thames*, the Diameter of the Wheel is 24 Foot, and about 5 or 6 Foot wide, and the Surface, or general Height of the Water in the largeſt Mill Pond or Ponds, which the induſtrious Undertakers have in all the low Meadows ſo judiciouſly made—, is eight Foot; which Water falling on the Bottom of the Wheel at B, N°. 1. gives ſuch a Thruſt, as muſt, comparatively ſpeaking, move a Mountain. How much that Weight is, has been already demonſtrated.

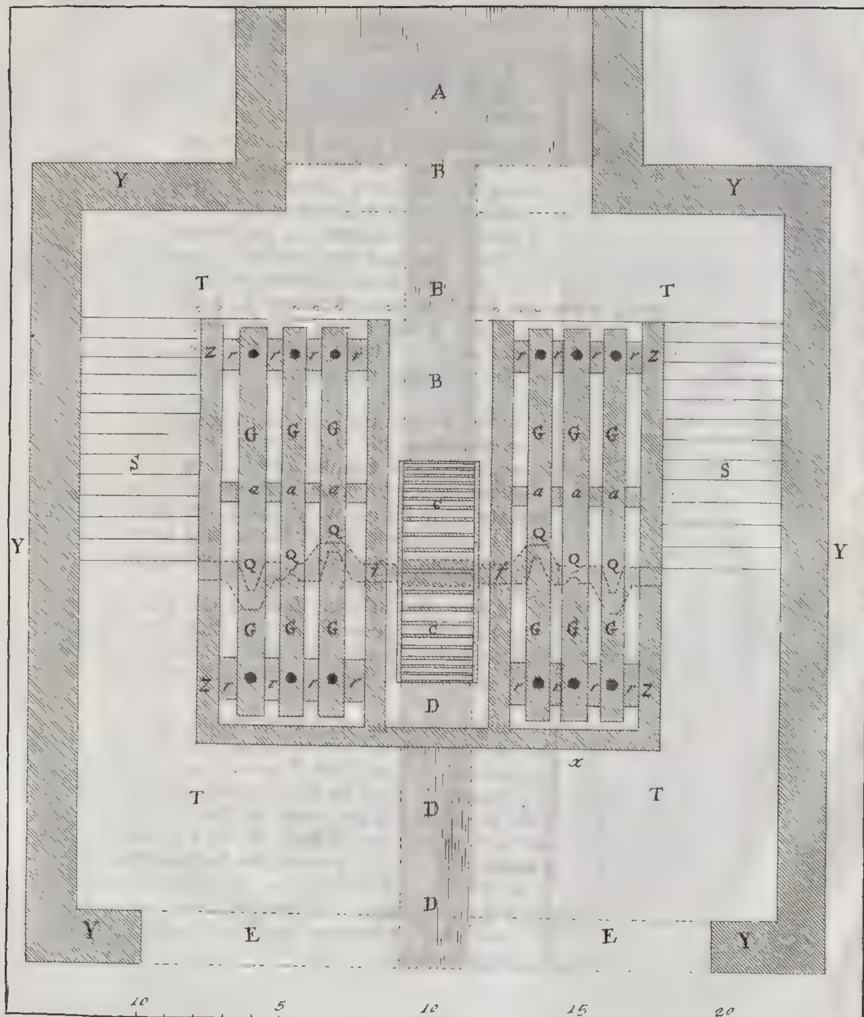
For the farther Demonſtration of this Engine, let it be added, that the Leavers *a a a a*, *&c.* are about 23 Foot in Length, which by the Movement of the Cranks *b b b b*, have a vibrating Motion turn'd as they are on the Fulcrum or Props at *o o o o*; *c c c c* are the Places where the four Piſtons which force the Water up, are fix'd, which being fix'd into thoſe largeſt Places, and have a Joint a little below it in the Rod, gives Way, and prevents that Friction that would otherwiſe be in the Barrels below.

Near to *k k k k*, *&c.* at each End, are the two Engine Trees, which having Pipes that come ſloping to them from the Coffers or Boxes where the Piſtons work, the Water takes its Courſe into the Pipe *l l*, thro' which it is flung up thro' the main Pipe, into any Place aſſign'd.

N N are paſſages or Gang-ways to go round the Engine, to mend it, to make Fires to keep it from freezing, and the like.

The Perſpective, *Fig.* 2d. *Tab. Prædict.* is ſo plain, that it needs no further Explanation than its own View, only at *a a a a* are the Joints in the Rods, which are made to give Play to theſe, and were there little Rowls or Wheels in the Channels or Mortiſſes above, it would ſtill help to prevent the Friction that is almoſt unavoidable in the Fall of the Piſtons, I ſay, almoſt unavoidable; for as the Regulators muſt of Neceſſity move upon one Axis or Center at *o o o o*, their Vibration muſt be circular, and their Fall not exactly perpendicular.

CHAP.



A Scale of Feet

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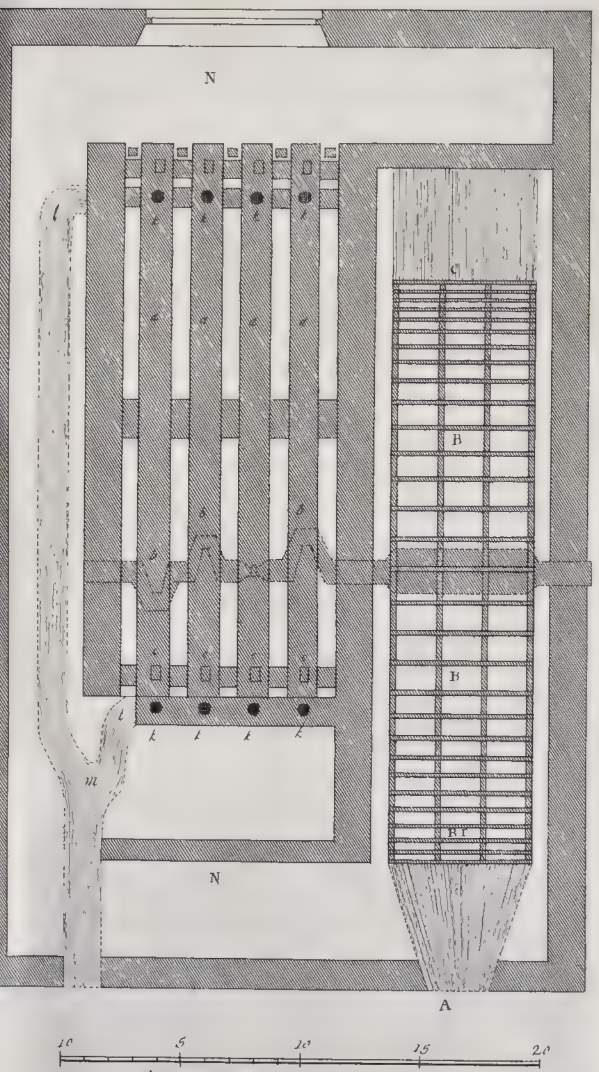
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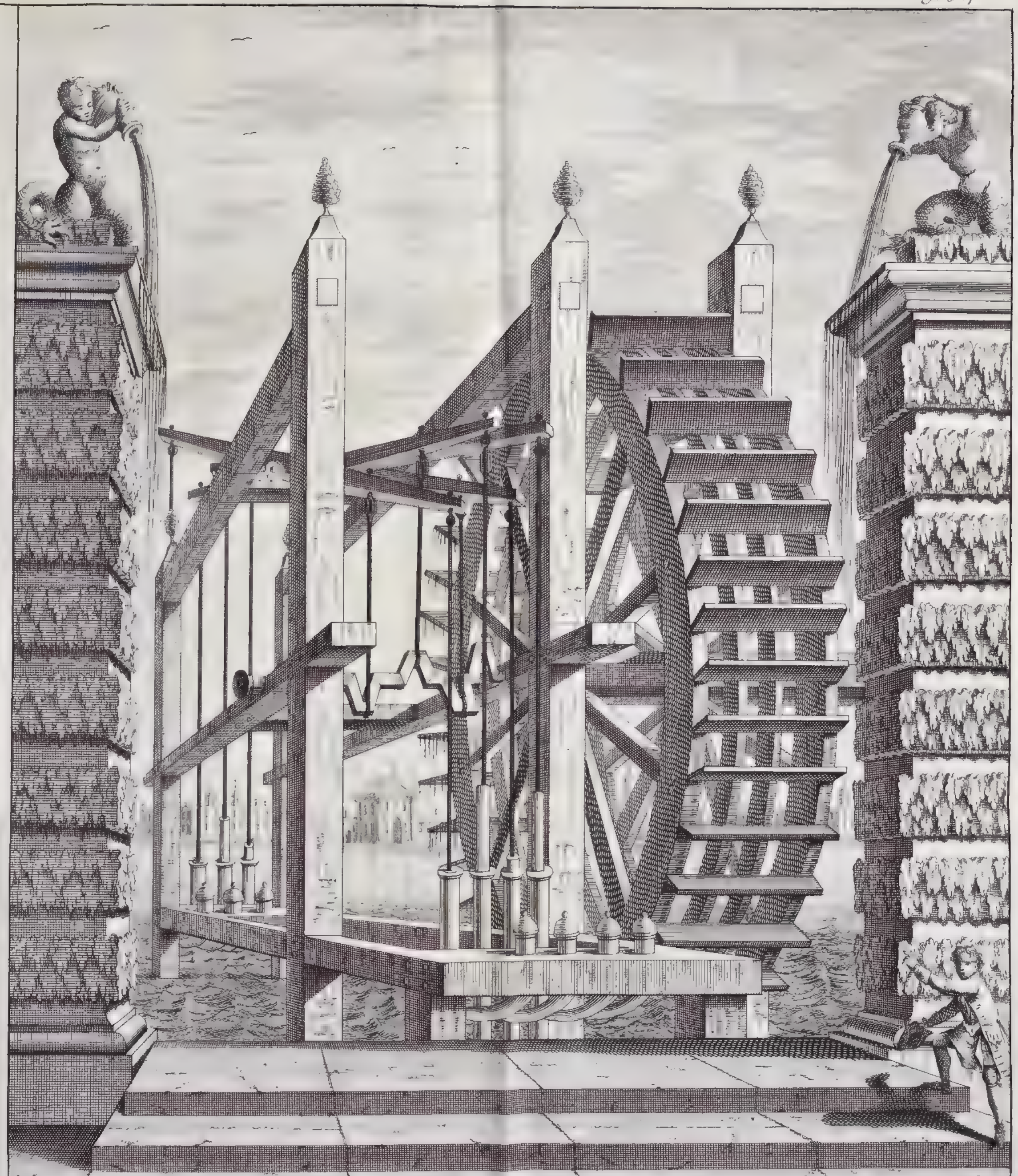


CHAP. XXVIII.

Of the Engine for raiſing Water by Fire.

AMONGST the ſeveral Engines which have been contriv'd for the raiſing of Water for the Supply of Houſes and Gardens, none has been more juſtly ſurpriſing, than that for the raiſing of Water by Fire; the particular Contrivance, and ſole Invention of a Gentleman, with whom I had the Honour long ſince to be well acquainted; I mean, the ingenious Captain *Savery*, ſometime ſince deceaſed, but then a moſt noted Engineer, and one of the Commiſſioners of the Sick and Wounded.

THIS Gentleman's Thoughts (as appears by a Preface of his to a little Book entituled, *The Miner's Friend*) were always imployed in Hydroſtaticks or Hydraulicks, or in the Improvement of Water-Works; and the firſt Hint from which it is ſaid he took this Engine, was from a Tobacco Pipe, which he immers'd to waſh or cool it, as is ſometimes done; he diſcover'd by the Rarefaction of the Air in the Tube by the Heat or Steam of the Water, and the Gravitation or Impulſe of the exterior Air, that the Water was made to ſpring thro' the Tube of the Pipe in a wonderful ſurpriſing Manner; tho' others ſay, that the learned Marquiſs of *Worceſter* in his *Century of Inventions* (which Book I have not ſeen) ſee *Page* 68. gave the firſt Hint for this raiſing Water by Fire.

IT was a conſiderable Time before this curious Perſon, who has been ſo great an Honour to his Country, could (as he himſelf tells us) bring this his Deſign to Perfection, on Account of the Aukwardneſs of the Workmen, who were neceſſarily to be imploy'd in the Affair; but at laſt he conquer'd all Difficulties, and procur'd a Recommendation of it from the Royal Society *in Tranſac.* N°. 252. and ſoon after, a Patent from the Crown, for the ſole making this Engine; and I have heard him ſay my ſelf, that the very firſt Time he play'd, it was in a Potter's Houſe at *Lambeth*, where tho' it was

a ſmall Engine, yet it forc'd its Way thro' the Roof, and ſtruck up the Tiles in a Manner that ſurpris'd all the Spectators.

About the Year 1699, he wrote a ſmall Pamphlet or Treatiſe concerning this Engine which I have juſt now mention'd, wherein he has exhibited a Draught of it, (which, with its Improvements, is to be found in the next Plate) as alſo, a particular Deſcription of its Uſes, which will follow in this Chapter: But as that conſiſted of a double Receiver, and a great many Particulars not ſo eaſy for a Learner at firſt Sight to underſtand, I have firſt of all inſerted that Draught, with the Account thereof, which Mr. *Bradley* in his *New Improvements of Planting and Gardening* has given us of that at *Cambden* Houſe, it being an Engine of Mr. *Savery*'s own Invention, and which is the plaineſt and beſt proportion'd of any that I have ſeen; and after that, I ſhall give the Author's own Drawings, and the Account by himſelf publiſh'd of his double Receiver, with the Improvements thereunto made, which are undoubtedly neceſſary in great Heights, and where great Quantities of Water are to be rais'd.

A Deſcription of the Fire Engine, Fig. 1. Plate 24.

A The Fire

B The Boiler; a Copper Veſſel of a ſpherical Figure, in which the Water is boiled and evaporated into Steam, which paſſes thro'

C The Regulator, which opens to let it into

D the Steam Pipe (of Copper) through which it deſcends into

E the Receiver, which is a Veſſel of Copper alſo, that at firſt ſetting to Work, is full of Air, which the Steam will diſcharge thorough

F the Engine Tree, and up the Clack at

K (the Plug of the ſaid Clack to come at and repair the ſame, if need be) and ſo the Air aſcends in

L the Force Pipe——, after E is void of Air, which is found by its being hot all over, then ſtop the Steam at

C and throw a little cold Water on at E, and the ſucking Clack will open at

I (which is the Plug of the ſaid Clack) and fill E with *Water, which will aſcend thorough*

G the Sucking Pipe from

H the Pond, Well, or River.

This being done, proceed to raiſe your Water, (*viz.*)

Firſt, Turn C to let the Steam paſs from the Boiler into E, and it will force the Water therein thorough F by K up L; which Water

4 can't

can't deſcend, becauſe of the Clack at I. When E is thus emptied, which may eaſily be perceived, by its being hot, as before, turn C, and confine your Steam in B; then open the Cock M, which will let a little cold Water into E, and that by condenſing the Steam in E, will cauſe the Water to aſcend immediately from H, and repleniſh E.

Then turn C, to let the Steam into E, and it will Force the Water out of it up L, into a Ciſtern at O, placed at the Top to receive it. Then confine your Steam at C, as before, and turn M for the ſpace of a Second or two of Time, and E will be refill'd, which may again be diſcharg'd up L, as before: So that this Work may be continued as long as you pleaſe, if you keep the Water in B.

If you turn the Cock N, and then only Steam comes out of it, (without hot Water) the Boiler muſt be repleniſh'd with freſh Water; but our Boiler of Water will laſt a long while.

When you have rais'd Water enough, and you deſign to leave off working the Engine, take away all the Fire from under the Boiler, and open the Lock N to let out the Steam, which would otherwiſe (was it to remain confin'd) perhaps burſt the Engine.

It muſt be noted, that this Engine is but a ſmall one, in Compariſon of many others of this Kind, that are made for Coal Works; but this is ſufficient for any reaſonable Family, and other Uſes required for it in watering all middling Gardens.

The Proportion of the ſeveral Parts of it as it now ſtands at *Cambden* Houſe, take from Mr. *Bradley*, as follows.

The Pipe from the Surface of the Water, to the Engine Tree F, is 16 Foot, which is the Length it ſucks the Water, or rather through which the Water is drove by the outward Force of the Atmoſphere; but as the aforeſaid ingenious Gentleman obſerves, might be made to draw or force Water (according to the Laws of Hydroſtaticks) 28 Foot very well; but according to the Rules before mentioned, to 33 or 34 Foot; however, in Attempts of this Kind, it is better to be under your Mark, than above it.

But to proceed from the Engine Tree F, up to the great Ciſtern which receives the Water, is 42 Foot (but as Mr. *Bradley* thinks) might be 100 Foot high, if ſuch a Quantity of Steam be allow'd as is proportionable to the Length of the Pipe.

The Diameter of the Bore, as well of the ſucking Pipe G, as of the force Pipe L, is three Inches; and of the Steam Pipe D about an Inch.

The Receiver holds 13 Gallons of Water, and the Boiler three times that Quantity.

When

When this Engine begins to work, you may raiſe four of the Receivers full in one Minute, which is 52 Gallons; and at that Rate, in an Hour's Time, may be flung up 3110 Gallons, which at 60 Gallons to the Hogſhead, is 52 Hogſheads: So that were this ſmall Engine to work, it would throw up 1248 Hogſheads (if Mr. *Bradley*'s Calculation is right) in 24 Hours. And if there were two Receivers, which is generally practis'd in Coal Works, the one to ſuck, while the other diſcharges it ſelf, then there would be rais'd 6340 Gallons in an Hour, which is 104 Hogſheads, and conſequently a Day would produce 2496 Hogſheads.

The prime Coſt of ſuch an Engine is about 50 Pound, as I my ſelf have had it from the ingenious Author's own Mouth, and the Quantity of Coals requir'd to work it, about half a Peck, which need not be renew'd above 6 or 8 Times, were it to be wrought the whole 24 Hours, which ſuppoſing to be a Buſhel at moſt, is not above 12 *d.* in *London*, but much cheaper in many other Places; the Expence is not conſiderable to what Horſe Work is, which muſt be ſhifted twice or thrice a Day, eſpecially in all Coal and Wood Countries, where Horſes are likewiſe generally let at dearer Rates, than at other Places, on account of that greater Quantity of Carriage there is in thoſe Places, more than is in others.

The chief Thing that ſeems to be objected againſt the Nature of the Engine juſt mention'd as to the Expence, is the making the Fire in the open Air as it were, and under a Trivet; becauſe the Heat in ſuch a Latitude will evaporate, and not be ſo ſtrong, as when it is confin'd into a narrow Compaſs, and conſequently there muſt be a greater Expence and Waſte of Wood and Coal, than when it is thus contracted, which makes it, I think, better to have the Fire enclos'd in a Stove or Furnace, than under any open ſpherical Figure.

Proceed we now then to the double Receiver, as we have it from the firſt Thought of our ingenious Inventor, and after that, to the Improvements that have been ſince made to it.

A Deſcription of the double Fire Engine, and of the Method of working it, Plate 24. Fig. 2 and 3.

The foregoing Chapter treating of the Method of working the ſingle Fire Engine, which may ſerve for the Supply of any reaſonable ſmall Family, and Gardens thereunto belonging, it is requiſite in the next Place, that we conſider the double Barrel and double Furnaced one, which is requir'd in all large Buildings and Gardens,

as

as well as Mines, and other deep Places, which is extracted from the Author's own Account of it, in a little Treatiſe before mentioned, call'd, *The Miner's Friend*, publiſh'd alſo in the Tranſactions of the Royal Society, *Numb.* 252.

A Deſcription of the Engine, Plate 24. Fig. 1.

A, The Furnaces.
B B, The two Fire Places.
1 2
C, The Funnel or Chimney.
D, The ſmall Boiler.
E, The Pipe and Cock of it.
F, The Screw that covers and confines the Force.
G, A ſmall Cock to a Pipe going within eight Inches of its Bottom.
H, A larger Pipe going the ſame Depth.
I, A Clack on the Top of the ſaid Pipe.
K, A Pipe going from the Box of the ſaid Clack or Valve, into the great Boiler, about an Inch into it.
L, The great Boiler.
M, The Screw with the Regulator.
N, A ſmall Cock and Pipe going half Way down the great Boiler.
O O, Steam Pipes, at one End of each are
1.2, Screws to the Regulator, and the other End to the Receivers.
P P, The Veſſels call'd Receivers.
1.2, Screws to P P.
Q. The Screws which bring on the Pipes and Clacks into the Front of the Engine.
R R R R, Numb. 1. 2. 3. 4. Valves or Clacks of Braſs, with Screws to open and come at them upon Occaſion,
S, The Force Pipe.
T, The ſucking Pipe.
V, A ſquare Frame of Wood, with Holes round its Bottom in the Water.
X, A Ciſtern, with a Buoy Cock, coming from the Bottom of the ſaid Ciſtern.
Z, The Handle of the Regulator.

The Manner of working this Engine is, firſt, there is a good double Furnace, ſo contriv'd, that the Flame of your Fire may circulate round, and encompaſs your two Boilers to the beſt Advantage, as you do Coppers for brewing. Before you make any Fire, unſcrew

G and N, being the two ſmall Gauge Pipes and Cocks belonging to the two Boilers. And at the Holes fill L the great Boiler two thirds full of Water, and D the ſmall Boiler quite full; then ſcrew in the ſaid Pipes again as faſt and tight as poſſible. Then light the Fire at B N°. 1. When the Water in L Boils, the Handle of the Regulator mark'd Z, muſt be thruſt off from you as far as 'twill go, which makes all the Steam, riſing from the Water in L, paſs with irreſiſtible Force through O N°. 1. into P. N°. 1. making a Noiſe as it goes; and when all is gone out, the Bottom of the Veſſel P, N°. 1. will be very hot. Then pull the Handle of the Regulator towards you; by which Means you ſtop O. N°. 1. and force your Steam through O. N°. 2. into the P. N°. 2. until that Veſſel has diſcharg'd its Air through the Clack R. N°. 2. up the Force Pipe. In the mean Time, by the Steam's condenſing in the Veſſel P. N°. 1. a Vacuum or Emptineſs is created, ſo that the Water muſt and will neceſſarily riſe up through I the ſucking Pipe, lifting up the Clack R. N°. 3. and filling the Veſſel P. N°. 1.

In the mean Time, the Veſſel P. N°. 2. being emptied of its Air, turn the Handle of the Regulator from you again, and the Force is upon the Surface of the Water in P. N°. 1. which Surface being only heated by the Steam, it does not condenſe it, but the Steam gravitates, or preſſes with an elaſtick Quality like Air; ſtill increaſing its Elaſticity or Spring, till it counterpoiſes, or rather exceeds the Weight of the Water aſcending in S the forcing Pipe; out of which the Water in P. N°. 1. will be immediately diſcharg'd, when once gotten to the Top; which takes up ſome Time to recover that Power, which having once got, and being in Work, it is eaſy for any one that never ſaw the Engine, after half an Hour's Experience, to keep a conſtant Stream running out the full Bore of the Pipe S. For on the out-ſide of the Veſſel P. N°. 1. you may ſee how the Water goes out, as well as if the Veſſel was tranſparent; for as the Steam continues within the Veſſel, ſo far is the Veſſel dry without, and ſo hot, as one is ſcarce able to endure the leaſt Touch with one's Hand; but as far as the Water is, the ſaid Veſſel will be cold and wet, where any Water has fallen in it; which Cold and Moiſture vaniſhes as faſt as the Steam in its Deſcent takes Place of the Water. But if you force all the Water out, the Steam, or a ſmall Part thereof going through R. N°. 1. will rattle the Clack ſo, as to give ſufficient notice to pull the Handle of the Regulator to you; which at the ſame Time begins to force out the Water from P. N°. 2. without the leaſt Alteration of the Stream; only ſometimes the Stream of Water will be ſomewhat ſtronger than be-

3 fore,

fore, if you pull the Handle of the Regulator before any conſiderable Quantity of Steam be gone up the Clack R. N°. 1. but it is much better to let none of the Steam go off (for that is but loſing ſo much Strength) and is eaſily prevented, by pulling the Regulator ſome little Time before the Veſſel forcing is quite emptied. This being done, immediately turn the Cock or Pipe of the Ciſtern X on P. N°. 1. ſo that the Water proceeding from X through L Y (which is never open, but when turn'd on P. N°. 1. or P. N°. 2. but when between them is tight and ſtanch) I ſay, the Water falling on P. N°. 1. cauſes by its Coolneſs the Steam (which had ſuch great Force juſt before) by its elaſtick Power, to condenſe, to become, in the Language of our Author, a Vacuum, or empty Space. So that the Veſſel P. N°. 1. is by the external Preſſure of the Atmoſphere, or what is vulgarly call'd Suction, immediately refilled, while P. N. 2. is emptying: Which being done, you puſh the Handle of the Regulator from you, and throw the Force on P. N°. 2. cauſing the Steam in that Veſſel to condenſe, ſo that it fills while the other empties: The Labour of turning theſe two Parts of that Engine, *viz.* the Regulator and Water-Cock, and tending the Fire, being no more than what a Boy's Strength can perform for a Day together.

The ingenuous Reader will probably here object, that the Steam being the Cauſe of this Motion and Force, and that Steam is but Water rarified, the Boiler L muſt in ſome certain Time be emptied, ſo as the Work of the Engine muſt ſtop to repleniſh the Boiler, or endanger the burning out, or melting the Bottom of the Boiler.

To anſwer which, be pleas'd to obſerve the Uſe of the ſmall Boiler D. when it is thought fit by the Perſon tending the Engine, to repleniſh the great Boiler (which requires an Hour and an Half, or two Hours Time, to the ſinking one Foot of Water): Then, I ſay, by turning the Cock of the ſmall Boiler E, you cut off all Communication between S the great Force Pipe, and D the ſmall Boiler; by which Means D grows immediately hot, by throwing a little Fire into B. N°. 2. the Water of which boils, and in a very little Time it gains more Strength than the great Boiler; for the Force of the great Boiler being perpetually ſpending and going out, and the other winding up, or increaſing, it is not long before the Force in D exceeds that in L; ſo that the Water in D being depreſs'd in D by its own Steam or Vapour, muſt neceſſarily riſe through the Pipe K into L, running, till the Surface of the Water in D is equal to the Bottom of the Pipe H.

Then the Steam and Water going together, will by a Noiſe in the Clack I give ſufficient Aſſurance, that D has diſcharg'd and emptied itſelf into L, to within eight Inches of the Bottom: And in as much as from the Top of D, to the Bottom of its Pipe H, is contain'd about as much Water as will repleniſh one Foot; ſo you may be certain, L is repleniſh'd one Foot of courſe: Then you open the Cock I, and refill D immediately.

By which you will ſee, that here is a conſtant Motion, without Fear or Danger of Diſorder or Decay; and if you would at any Time know if the great Boiler L be more than half exhauſted, turn the ſmall Cock N, whoſe Pipe will deliver Water, if the Water be above the Level of its Bottom, which is half Way down the Boiler, if not, it will deliver Steam.

So likewiſe will G ſhew you, if you have more or leſs than eight Inches of Water in D, by which Means nothing but a ſtupid Neglect, or miſchievous Deſign carried on ſome Hours, can any Ways hurt the Engine. And if a Maſter is ſuſpicious of the Deſign of a Servant to do Miſchief, it is eaſily diſcovered by thoſe Gauge Pipes: For if he comes when the Engine is at Work, and finds the Surface C of the Water in L, below the Bottom of the Gauge Pipe N, or the Water in D below the Bottom of G. ſuch a Servant deſerves Correction; tho' three Hours after that, the working on would not damage or exhauſt the Boilers: So that in a Word the Clacks being in all Water-Works always found the better the longer they are us'd; ſo here the ſame Effect is found, and all the moving Parts of the Engine being of like Nature, the Furnace being made of *Sturbridge* or *Windſor* Brick, or Fire Stone, I don't ſee it poſſible for the Engine to decay in many Years.

For beſides all the Clacks, Boxes, and Water-Pipe, Regulator, and Cocks are all of Braſs; and the Veſſels are made of the beſt hammer'd Copper, of ſufficient Thickneſs to ſuſtain the Force of the Working-Engine: In ſhort, the Engine is ſo naturally adapted to perform what is requir'd, that even thoſe of the moſt ordinary and meaneſt Capacity may work it for ſome Years without Injury, if not hired or employ'd by ſome baſe Perſon on Purpoſe to deſtroy it: For after the Engine is once fix'd, and at work, I may modeſtly affirm, that the Adventurer or Superviſor of the work will be freed from that perpetual Charge, Expence and Trouble of Repairs, which many Engines are generally liable to.

Thus far the Ingenious Captain *Savery* as to the Working of his Engine; many other Inſtructions has he likewiſe left us to the fixing

fixing his Engine, for the Service of Gentlemens Houſes, Coal-Works, *&c.*

ALL which, with other Neceſſaries, may I think be ſumm'd up in theſe few Lines, that the Engine be fix'd on the higheſt Ground, or as near as poſſible the Reſervoir that is to ſupply the Houſe and Gardens, if in the open Air; for the Advantage of this as well as the Chain-Pump, is that you may uſe them on the higheſt Hill, and they certainly ſave that Expence of Pipe which is unavoidable where-ever you force up your Water by Crank-Work, not but they are uſeful where Cranks are too. But if you are to force up your Water to the Top of a high Tower, then of courſe you muſt place your Engine therein, and one and the ſame Building will ſerve.

IT is obſervable, that all thoſe Engines that are plac'd ſo as to raiſe Water to a conſiderable Height, that the Furnaces are plac'd about 21, 22 or 23 Feet, and ſometimes more, above the Surface of Water in the Well or Pond, out of which you are to draw the Water; becauſe the external Preſſure of the Air, or in other Words the Atmoſphere forces the Water by Nature up to that Height where this Engine takes it, as it does in all other Pumps and Engines.

TO follow our Author for Palaces, or the Nobility's, or Gentlemens Houſes, you may fix the Engine in any remote or out-Room, whoſe Floor as before is not above 20 or 25 Foot from the Level of your Water; but in Caſe the Surface of the Water is apt to riſe and ſink, as many Springs are apt to do, there you muſt take the loweſt: But you may continue your force Pipe up to the Top of your Houſes, be it 70, 80 or 100 Feet, making your Furnaces either larger or ſmaller, according to the different Heights you are to throw your Water; at the top of which Houſe you are to fix your Ciſtern, into which the Pipes alſo muſt be laid that are to convey the Water to its ſeveral Uſes.

THIS way of Ciſterns on the Tops of Houſes or Palaces would be of ſingular Uſe in caſe of Fire, as is ſaid before; for in every Stair-Caſe a Pipe may go down the Corner, or behind the Wainſcot, ſo as to be no Blemiſh even to the fineſt Stair-Caſe.

AT every Floor there may be a Turn-Cock with a Screw; at the utmoſt End you may likewiſe have a ſmall Leather Pipe kept well oil'd in a Cupboard or Cavity in your Wall, which may not be ſeen but on the opening ſome Part of the Wainſcot; or ſuch other Contrivance as the Ingenious Builder ſhall think fit to make uſe of. This Pipe of Leather muſt be long enough to reach from the Landing Place or Stair-head into all the Rooms adjoyning to it.

ONE

One End of this Pipe may have a Screw to fit the Cock in the other Pipe; and at the other End a Pipe like the Noſe of a Pair of Bellows; ſo that wherever, though under a Bed, or the remoteſt part of any Room in the Houſe, the Fire breaks out or is diſcover'd; any Servant having ſcrew'd the Pipe to the Cock, ſtops the Noſle with his Thumb till he comes to the Place where the Fire is, when taking away his Thumb, he by directing the Noſle to the Fire, immediately extinguiſhes it; which being liable to be inſtantly uſed, I think a Houſe, Palace, &c. that has this Invention, may be ſaid to be morally out of Danger of being deſtroy'd or ſo far injur'd, as *Whitehall* and *Kenſington* have within theſe few Years been.

This Command of Water muſt be allow'd to be a vaſt Advantage to any Houſe whatſoever, where Brewing, Waſhing, &c. is uſed; the Copper ſtanding high, may be fill'd as eaſy as if it ſtood low, by which means the hot Liquor may be contriv'd to go to all your Coolers and other Veſſels, either by a Siphon, Stop-Cock and the like, without the Labour of Pumping or Boiling with Buckets.

How uſeful it is in Gardens and Fountain-Works may or might have been ſeen in the Garden of that Right Noble Peer the preſent Duke of *Chandois*, at his late Houſe at *Sion-Hill;* where the Engine was plac'd under a delightful Banquetting-Houſe, and the Water being forc'd up into a Ciſtern on the top thereof, us'd to play a Fountain contiguous thereto in a very delightful Manner.

For the Draining of Fens and the like, this Engine is no leſs uſeful, but muſt be made very large in the Bore of the evacuating Pipe; for at all ſmall Heights a ſmall Quantity of Fire will deliver a prodigious Quantity of Water. For ſuppoſe we ſuck twenty Foot, if the Boiler does but fill the Veſſels called Reſervers, with Stream ſtrong enough to counterpoiſe or exceed the Force of the Atmoſphere, or Spring of the common Air, it will diſcharge them at ſo ſmall a Height as 30 Foot Force in a very little Time: And the Steam having very little Force is immediately condenſed, ſo that it will preſently ſuck full, in one of the Veſſels, while the other is diſcharg'd.

Now in as much as the Fire being more or leſs, adds nothing to the Suction; I think ſuch Lifts being ſeldom above 36 or under 6 Foot, all the Directions farther needful for the fixing the Engine for this Uſe, is in all Lifts under 20 Foot; to place your Engine ſo as a little above your Force-Clacks, may be the Place of the Delivery of your Water into a convenient Reſervoir or Trough, to be carried off at the moſt proper Place for its Diſcharge.

If it be any Height above 24 Foot or thereabouts, you have nothing to do but to continue the Length of your force Pipe to the Height

Height requir'd; it ought to have a Shed or Covering, not only in this (but in all other Places) and to be plac'd at the loweſt Place of your Fen or Bog, as other Engines deſign'd for that Purpoſe generally are: And thus much of the Uſes and Manner of fixing it, as I have it from the Author, or from what has occur'd to my own Obſervation on this Head; as for the Working of it in Mines and Coal-Pits, I refer the Reader to the Author's Treatiſe it ſelf, as it is Printed for *S. Crouch* at the Corner of *Pope's-Head-Alley* in *Cornhill*, *Anno* 1702.

PROCEED we now, according to Promiſe, to a Capitulation of the Improvements that have been made to this uſeful Engine, which will be in a great Meaſure ſumm'd up in that Noble Engine erected for the Uſe of the *York-Buildings*.

TO finiſh this long Account of the ſurpriſing Engine for the raiſing of Water by Fire: I produce this laſt Improvement of it by Mr. *Thomas Newcomen*, which makes it undoubtedly the beautifulleſt and moſt uſeful Engine that any Age or Country ever yet produc'd.

THE following, *vid.* Machine, *Plate* 25. differs in no eſſential Part from that ſet up at the *York-Buildings*, only the Pump-Work is double: And all Engines that are in Mines have their Pumps under Ground, fix'd in the Pit: The Pumps being either ſucking, lifting, or forcing Pumps, according to the Conveniency or Circumſtances of the Place.

CHAP.

CHAP. XXIX.

A Description of the Engine to raise Water by Fire, fix'd in a Frame of Timber instead of the usual Engine-House, as Improv'd by Mr. NEWCOMEN.

A 1, A 2, THE Leaver, or great Beam of the Engine, moving upon its Centre at C, whose Ends are alternately pull'd down by the Piston in the Cylinder, and by the Plug or Forcer of the Pump.

a 1, *a* 4, *a* 2, *a* 3, The Arches fix'd to the Ends of the Beam, to carry the Chains that sustain the Piston and the Plug; in order to have the Strokes perpendicular in the Cylinder, and the Forcing-barrel or Working-piece, in the Lines *a* 4 and *x* 6.

C *c* 1, C *c* 2. Two strong wooden Springs, to weaken the Blow given by the Bars at the Ends of the Leaver when the Stroke is too long, that the Machine may not receive too great a shock.

a 1, *a* 2. Two strong Iron Bars crossing the two extreme Arches of the Leaver, to prevent the Ends from coming down too low in case the Chain at either end should break.

D. Another little Arch upon the Beam, to carry a Chain that draws up and lets down the working-Timber *p p* 1, *p p* 2, (by the Engineers belonging to the Mines call'd *the Plug-Frame)* which, in rising and sinking perpendicularly, does, by its several Pins, alternately open and shut the Regulator T, and the Injection-Cock *m*.

E. The Rod which, hanging at the Chain of the Arch *a* 2, *a* 3, draws up and lets down the loaded Forcer or Plug; which Forcer, by its motion in the Working-piece, or Forcing-barrel F, brings up, out of the Well under it, and forces up thro' the Pipes, into the Reservoir, a Column of Water almost as heavy as the said Forcer; which

which is only loaded with ſo much more weight as to give the Water a ſufficient Velocity, that the Quantity requir'd may be rais'd and deliver'd into the Reſervoir in a given time: And, that neither Air nor Water may paſs between the ſaid Forcer and Barrel, it goes thro' two Collars of Leather, which are ſcrew'd between three Rings of Metal fix'd on the upper Flanch of the ſaid Forcing-barrel. The middle Ring is of Braſs, and ſerves for a Guide to the Forcer, being of a leſſer bore than the other two, which are of Iron, that neither the upper Leather nor the lower Leather (one whereof is turn'd upwards, and the other downwards) may ſlip between the Forcer and the middle braſs Ring; as may be ſeen in Fig. 3, which repreſents a Geometrical Section of the Pump-work, ſeen in front, with the Forcer, Rod, Screws, and Weights; the two ſucking and forcing Valves; part of the ſucking Pipe, and part of the forcing or aſcending Pipe; the ſmall Pipe, which diſcharges the Air, with its Cock and Valve; the leaden Cup with Water (to the height of the pointed Line) to moiſten the Leathers which are repreſented by ſtrong black Lines.

F 8, 10, 9, 7, H 6, G 1. (*Vid. Fig.* 2. *Plate* 25) is The Pump-work, conſiſting of the following Pieces, *viz.* F 7, 8, the Forcing-barrel, which is bigger in its Bore at 7, 8 than in any other part, to allow ſufficient Water-way, when the ſucking Valve fix'd at the level of 9, 10 riſes up as the Forcer is rais'd. This Barrel has a curve Elbow H coming out of it juſt above the ſucking Valve, and the Elbow has a Flanch under 6, to carry the forcing Valve which plays in the ſwell 6 of the Piece 6, G 1. The ſucking Pipe which goes down into the Well has only its Flanch 9, 10, and a ſmall part below it (mark'd 11) ſeen here: And it is upon this Flanch 9, 10 (the Flanch of the forcing Barrel) that the ſucking Valve is fix'd, which riſes when the Forcer is lifted up, and allows the Water to riſe which the Atmoſphere preſſes up from the Well, to fill the ſpace left empty by the Forcer; the forcing Valve under 6 being ſhut all this while: Then, as the Forcer comes down again, it preſſes a quantity of Water equal to its bulk thro' the forcing Valve under 6 into the Piece G 1, the ſucking Valve being ſhut at that time; and ſo on, till the Water is driven up thro' the Pipes G 1, G, G, G, into the Trough I, I, which carries it into the Reſervoir K, K, K, K, K, K, K. NB. *The Forcer is a hollow braſs Cylinder fill'd with Lead, turn'd true and ſmooth on the outſide.*

L, The Injection Ciſtern, for the Uſes of the Engine, to be mention'd hereafter.

M, M, M, M, The two ſtrong Timbers which ſupport the Leaver by its Centre or Axis, and between which the Leaver plays.

N, The Chain that fupports the Pifton, which always hangs perpendicular, becaufe its upper part always applies it felf to the Arch at the end of the Leaver, whilft the free part is a Tangent to the faid Arch.

O, O 1, O 2, The Injecting Pipe, which coming from the Injecting Ciftern L at O 2, gives out a little Pipe at O 1, to let Water run upon the Pifton, to keep it tight, by moiftening and cooling its Leather, and at laft goes into the Cylinder at O thro' a Flanch, in fuch manner, that an Adjutage or fpouting Pipe is fcrew'd on the upper part of the end of it which is in the Cylinder. The Ufe of this Pipe is, to fpout cold Water into the Cylinder, in order to condenfe the Steam, and make a *Vacuum* under the Pifton, when it has been rais'd up to the top of the Cylinder, that the Atmofphere may prefs it down again with force and fwiftnefs.

P 1, P 2, The Cylinder, made of Brafs, hollow within, and bor'd very fmooth, that the Pifton P 1, mark'd in pointed Lines, may move up and down in it from P 1 to P 2, without letting either Steam or Water pafs by. This Cylinder has a leaden Cup folder'd to the top of it under N, fo wide, that the Water that lies at the top of the Pifton to cool its Leather may not flafh over the top of the Cylinder in the fudden rifing of the Pifton.

Q, The Steam-pipe, thro' which the Steam paffes from the Boyler into the Cylinder.

R, R 1, R, R, R 2, The Boyler, made hemifpherical at top, and then diminifhing at right Angles, or with a Flanch, at R 1, R 2, and fo continuing almoft in a Cylindrick form to the bottom; which is rifing in the middle, as appears by the pointed Lines.

S, A brafs Plate fcrew'd to the Boyler with four or more Screws, which, when taken off, opens a way into the Boyler in order to cleanfe it, &c. On this Plate is faften'd a fhort Pipe and Valve, S 1, with a Stillyard and Weight fupported by a perpendicular Piece, S 2, in order to know the ftrength of the Steam in the Boyler, and to prevent its burning, if neglected. In this Plate are fix'd two Gage-Cocks, *z* 1, *z* 2, whofe Pipes are of different Lengths, in order to know how high the furface of the Water is in the Boyler; for if both Cocks, being open'd, give Steam, the Water is too low; and if both give Water, or give no Steam, then the Water is too high; but if *z* 1 gives Steam, and *z* 2 does not, then the furface of the Water is at a due height, *viz.* above *z* 3, the bottom of the longeft Gage-pipe.

T, The Steam-Cock or Regulator, confifting of a large brafs Plate and a Pipe reaching up to Q, which makes half of the Steam-pipe, and is there folder'd to the other half that comes down from the

the bottom of the Cylinder. By means of the Handle b b, a little smooth Plate, mark'd 16 (Fig. 2.) under the Regulator Plate, is mov'd in such manner, as alternately to shut and leave open the hole of the Steam-pipe, so as to perform the Office of a Cock, but with a great deal less Friction.

V, A Cock to let Water out of the Boyler upon occasion.

W, A Pipe to feed the Boyler with lukewarm Water from the Cup at the top of the Piston, thro' the Feading-pipe *n n*, which goes down into the Boyler within a few Inches of its bottom, that there may always be a due Quantity of Water in the said Boyler.

X X, A waste Pipe to carry off the superfluous Water from the Cup at the top of the Piston.

Y Y Z, The Sinking-pipe to carry off the Water which is injected into the Cylinder at every stroke, whose end Z (mark'd in pointed Lines) is turn'd upwards with a Valve upon it, kept tight (when shut) by a little Water in the hot Well Z: But every time the Steam is let into the Cylinder, it opens the Valve at Z, and discharges the Water, as long as the said Pipe Y Y continues full, or nearly full, to help the Steam by the pressure of its Water, which is always proportionable to its height in the said Sinking-pipe.

a, a, a, a, a, a, The Chimney and Brickwork about the Boyler, being here seen only on the back-side; the Fire-place, represented by the pointed Lines at &, being on the other side, and the Flue carried round the Boyler, under its Flanch.

b b, The Handle of the Regulator, mov'd backward and forward by the Motion of the Slider b *c*.

d, *d* 1, The Tumbling-piece, commonly call'd the [Y] from its Figure, moveable upon an Axis *e e* by means of the Shanks *g h* and *g g*, which are thrown backwards and forwards, by the Pins in the Working-timber, or Plug-frame, one Pin *a* (on its outside) depressing *g g* in the descent of the Working-timber, so as to throw the Head of the [Y] loaded with Lead to *d* 1 (as here in Fig. 1. and Fig. 2) whilst one of its Toes, at the other end, striking the Pin *c d*, shoots forward the Slider, and opens the Regulator: Then a Pin or Roller upon a Pin *b b*, in a Slit made thro' the middle of the Working-timber, in the rising of the said Timber, lifts up the Shank *g h*, and throwing the Weight *d* 1 towards the Cylinder, causes the other Toe at the contrary end of the [Y] to strike the Pin *c d* on the inside, and thereby pulls back the Slider to shut the Regulator.

f 1, *f* 2, A small Iron Leaver, commonly call'd the [F], moveable upon its Axis *r*, which is fix'd in the piece *i*; whose Office is to open and shut the Injection-Cock *m*, by means of two Toes *n*, *o*, which

take between them the Handle of the said Cock *m*. The Centre of this Leaver is above its Toes, between *f* 1, *f* 2; and one of its ends *f* 2 lodges it self in the Notch of the Catch *r* 1, whose Foot is fix'd upon the Axis *r* of the said Leaver. When the Working-timber ascends, a Tooth, which is fix'd on the side of it that looks towards the Cylinder, express'd here in pointed Lines, raises up the outmost end of another Catch mark'd q, (one part of which is hid by the Working-timber *p p)* and consequently draws down the farther end, which takes along with it the nearest end of the Catch *r* 1, which is upon the same Line, and close to the other, whilst the end p of the said Catch *r* 1 rises towards *s*, and thereby lets fall out of the Notch the end *f* 2 of the Leaver, which, being pull'd down by the Weight *f* 3 fix'd to it, causes one of the Toes, mark'd *n*, to push towards the Working-timber the Handle of the Cock *m*, which thereby gives the Injection: Then, as the Working-timber descends, by a Pin on its further side it pushes down the Curve-end or longest Shank of the [F] *viz.* f 1; and raises up the other end of it, so as to lodge it in the Notch of the Catch *r* 1; the other Toe, mark'd *o*, pushing the Handle forward at the same time, and thereby shutting the Injection immediately before the opening of the Regulator: as the Injection afterwards must be open'd just after the shutting of the said Regulator. From the Beams which support the Cylinder there come generally two descending Pieces, to carry the Machinery that turns the Regulator and Injection-Cock, commonly call'd the [F] and [Y], at a due distance from the Working-timber; but here, for want of room, two Iron Bars are us'd, one of which is mark'd *i* 3, *i* 4, join'd at bottom by a cross Bar, and with Side-pieces *i*, *i* 1, *i* 2, to carry the Axes of the [F] and [Y]: The other descending Iron Bar can't be seen in this Draught, as being hid by the Working-timber. NB. *For the better understanding of the Motion of the Machine, the Regulator and Injection-Cock, with the other Parts belonging to them, are drawn in large in the same point of Sight, and are mark'd with the same Letters in Fig.* 2.

k k, The two ends of a Strap of Leather fasten'd to the top of the [Y] at *d* 1, to keep it from falling too far either way.

l, The *snifting* Valve, to let out the Air that extricates it self from the injected Water at every stroke, and which would hinder the due Operation of the Engine, if it was not driven out at this Valve.

o, A Cup and Valve to receive some of the injected Water, which is much hotter than the Water above the Piston: From this Cup hot Water is convey'd into the Feeding-pipe *u n*, by the Cock *o* 1.

p, *p* 1, *p*, *p* 2, The Working-timber, hanging by a Chain which applies it ſelf to the Arch D, and moving up and down perpendicularly thro' the holes *p* 1, *p* 2, made to keep it ſteddy in its motion. This Timber has a Slit in the middle from *p* 1 down below *p*, in order to receive the Shank *g h*, and to throw it back again by a Pin *b b*, or Roller on the Pin, in the ſaid Slit. There are alſo Holes on the right and left ſide of this Timber to put in Pins, as *a*, and *d*, alternately to depreſs the Handle *g g* on the one ſide, and the long Shank of the [F] on the other ſide, according as the motion of the Engine requires.

q, *q*, *q*, *q*, Two ſtrong horizontal Timbers that ſupport the Cylinder by means of a Flanch on the middle of the Cylinder, and Bolts and Screws thro' the ſaid Beams.

r 1, *r* 2, A croſs horizontal Timber, broken off in the Figure, to ſhew the Cylinder and Pipes, *&c.*

s, *s*, *s*, *s*, Braces alſo broken off.

t, *t*, A Seat and Platform to go from the Working-piece to the Pump.

u, *u*, One of the upright Timbers that ſupport the Spring-frame and Pipes join'd to the horizontal Piece at M, the other Timber being behind.

u 1, The braſs Guide for the Rod of the Forcer, which is here almoſt hid by the aſcending Pipes.

w, *w*, *w*, *w*, *w*, The Joyſts of the Floor, which is even with the middle of the Cylinder.

x, *x* 1, A Cup of Lead, which keeps moiſt the *Jack-head* or Collar of Leathers. NB. *At firſt working, the Air is let out of the* Jack-head *by looſening ſome of its Screws, or by a little Cock and Valve at x* 1.

y, A croſs Piece, which holds the Braſs Guide above-mention'd at *u* 1.

æ, A Pipe to ſupply the Injection-Ciſtern L with Water from the Reſervoir K.

Thus far of the Deſcription of the Engine to raiſe Water by Fire, as improv'd by Mr. *Newcomen.*

What I have to add in this Place is, that as the beſt and moſt uſeful Inventions and Improvements which have been diſcover'd either in Art or Nature, have in Proceſs of Time been liable to Improvement; ſo this of the Fire-Engine has been ſubject to the ſame: For this ingenious Gentleman, to whom we owe this late Invention, has with a great deal of Modeſty, but as much Judg-

ment,

ment, given the finiſhing Stroke to it. It is indeed generally ſaid to be an Improvement to Mr. *Savory*'s Engine; but I am well inform'd, that Mr. *Newcomen* was as early in his Invention, as Mr. *Savery* was in his, only the latter being nearer the Court, had obtain'd his Patent before the other knew it; on which Account Mr. *Newcomen* was glad to come in as a Partner to it. To which I ſhall add, that the Gravity of the Atmoſphere on the Cylinder, mark'd P 1. P 2. is computed to be equal to 1400 Weight, which nevertheleſs will not ſtop the working of the Engine, if the Stoker takes Care to keep his Fire in, and that this Engine is by no Means in ſo much Danger of being blown up, or broke to Pieces, as Mr. *Savery*'s is, by reaſon of the great Regulator, mark'd A 1. A 2. and of the other, Work at *f* 1. *f* 2.*&c.* which bridle the whole Motion of the Engine. And the utmoſt Damage that can come to it, is its ſtanding ſtill for want of Fire. What is very remarkable (beſides other Things which might be mention'd) is the wonderful Effects there is between the two oppoſite Principles of Expanſion and Condenſion, and how fully the Atmoſphere performs its Office on this Occaſion.

The Fall of the two Piſtons, or Braſs Barrels, which are joyn'd to the other End of the Leaver, mark'd *a* 3. *a* 4. is alſo very curious; becauſe that by Means of the Chain fix'd at the End going down to N the Force is exactly perpendicular, and the whole not liable to that Friction, which is almoſt unavoidable in all other Leaver Work.

The two Mains which lead from the 2 Barrels, or forcers from the Bottom to the Top of the wooden Turret, are each of them about 12 or 14 Inches Diameter, and deliver about 150 Tuns in an Hour, which is 3600 Tuns, or 14400 Hogſheads in a Day.

To conclude this Account of Engines, I obſerve, that there are 5 of thoſe Machines of *London Bridge*, one whereof is deſcrib'd *Plate* 21. *Page* 320. to every one of which is fix'd 4 main Pipes, two at one End, and two at another, in all 20, of 7 Inches Bore each; the Workmen there have not, as I can find as yet, calculated, (at leaſt it is out of Mind) what Quantity of Water, all thoſe Machines will throw up in an Hour, tho' if the Pipes are kept perpetually full, as an Engine with 4 Cranks certainly will, according to *Marriotte*, in 20 Mains, of 49 circular Inches each, making in all 980 circular Inches; thoſe Machines can't give leſs than 1715 Hogſheads in an Hour, and conſequently 45160 Hogſheads in a Day, equal, if not exceeding what the ſo much fam'd one of *Marli* does, and that without any great need of Repairs.

3 One

One Thing obſervable in the Wheels of thoſe Machines is, that they turn as the Tide does; thoſe which are plac'd near the Middle, are either elevated or depreſs'd by a little Wheel on the Back Part of the Work, called a lifting Wheel, as the Tide either riſes or falls, whilſt thoſe which are plac'd near the outſide, are kept to a conſtant Gauge, which is all I ſhall add in this Place as to theſe Machines.

CHAP XXX.

Of ſeveral Machines for the playing of Muſick.

I Have already, in my Introduction to this Book of Hydraulicks, noted, that it has had its real Denomination (though now it is generally applied to all Water Engines) from ὕδωρ *Aqua* Water, and αὐλός *Tibia vel Tibicen* a Pipe, from the Uſes which the Ancients put the Antlia or Pump to in blowing their Organs; and of this Kind there are Inventions of a late Date (as whoever reads *de Caus*, and other Authors, will find) by which Organs, and other Inſtruments of Muſick are play'd: And tho' this Chapter may not be of the greateſt Uſe, yet there is a Diverſion in it, that may not be unacceptable to the curious Reader.

To begin then with the learned *Graveſande*, the undulatory Motion in the Air produces Sound: For (ſpeaking of Senſation) ſo ſtrict is the Union of the Body and the Mind, (ſays he) that ſome Motions in the Body do as it were cohere with certain Ideas in the Mind, and they can't be ſeparated from each other. From the Motion of the Body are new Ideas every Moment excited in the Mind; and ſuch are the Ideas of all ſenſible Objects; yet we can find nothing common between the Motion in the Body, and the Idea in the Mind. We cannot perceive what Connection is here, nor that any Connection is poſſible: There are (according to the great Sir *Iſaac Newton*, whoſe Footſteps this learned Author follows) an infinite Number of Things hidden from us, of which we have not ſo much as an Idea.

The

THE undulatory Motion of the Air agitates the Tympanum or Drum of the Ear, by which Means a Motion is communicated to the Air contain'd in that Organ, which being conveyed to the auditory Nerve, excites in the Mind the Idea of Sound.

NOW, to explain a little thofe Laws of Motion, that produce Sound, let Particles of Air be fuppofed to be plac'd at equal Diftances, and to be in a right Line, *a, a, b, c, d,* &c. and *f, Fig.* 1. *Plate* 26. *Page* 352; let the Wave be fuppos'd to move along that Line, as far as between *h* and *p*, as it is reprefented in Line 1.

THE greateft Denfity is at *m*, which is the Middle between *h* and *p*, and the greateft Dilatation between (*b* and *h*) is in the Middle (*e*). Wherever the neighbouring Particles are not equally diftant, the Motion arifing from Elafticity caufes the lefs diftant Particles to move towards thofe that are moft diftant, between (*b*) and (*e*); there is a Motion from (*b*) towards *e* that is confpiring with the Motion of the Waves; there is alfo fuch a Motion between *n* and *p*; but there is a contrary Motion between *e* and *m*, and it is directed from *m* towards *e*. At *m* and *e*, where the Directions of Motions are chang'd, no Action arifes from the Elafticity, becaufe the neighbouring Parts are plac'd at equal Diftances amongft themfelves. In the Places *b*, *l* and *p*, the Difference of the Neighbouring Parts is the greateft of all; and therefore there is the greateft Action of the Elafticity.

BUT for this Motion or Progreffion of Sound, I refer my Reader to Book the 2d, *Chap.* 17. of *Gravefande*'s Mathematical Elements of Natural Philofophy, where it is treated of in a very exact Manner, having made ufe of the Figures in that Treatife fet down, for the Embellifhment of this Work.

AND to proceed, the Structure of the Ear, both internal and external, is wonderful, but that the Air is the Vehicle of Sound, is proved by the following Experiment.

TAKE the leaden Plate O, *Vid. Fig* 2. *Plate* 26. *Page* 352, which has two Cylinderical Pillars of the fame Metal C C fix'd to it; joyn a little Bell A to the Brafs Wire B D, and let it be tied with Strings to the Pillars C C; lay the Plate O upon the Brafs Plate of the Air-Pump, putting between a little Cufhion of Cotton, or raw Silk, fet a Receiver on over all this *Apparatus*. Cover the Receiver with a Plate that has a Collar of Leathers fcrew'd to it, thro' which the Brafs Wire D E can flip up and down; to the Brafs Wire you muft faften the Plate *e f*; fo that by twining of the Wire round, the Bell A may be agitated. Pump out the Air from the Receiver, and fhaking the Bell in the Manner before defcribed, you

3 will

will not hear the Sound. By turning the Wire D E, the Bell will move forwards and backwards ſeveral Times; but we are only to obſerve that Motion in which the Plate *e f* doth not touch the Wire *b d*. Letting in the Air, the Sound will be heard as before.

AND from this it is deducible, that Air is the Vehicle of Sound, and that in Sound there is an undulatory Motion of the Air, and that it ariſes from the tremulous Motion of Bodies. That this obtains in Cords or Strings of muſical Inſtruments, no body doubts, ſince by giving them a tremulous Agitation they produce a Sound; in great Bells, and other Bodies this tremulous Motion is very ſenſible, and in all other Bodies according to their Proportion.

IT appears alſo, that the Intenſity of Sound is as the Weight by which the Air is compreſs'd; that is, this Intenſity increaſes and decreaſes as the Pillar of Mercury, which is *in Equilibrio* with the Weight of the Atmoſphere, for which ſee *Fig.* 3. *Plate* 26. *Page* 350. where if you ſhake the Bell A in compreſs'd Air exactly in the Manner as it was ſhak'd *in vacuo*, the Sound will be encreas'd; which will again be diminiſh'd, if opening the Bell, you let the Air return to its firſt State. For a further Demonſtration of what we are upon; and that Air is the certain Vehicle of Sound, which is leſs or more Intenſe according to the Warmth or Coldneſs of the Weather, *i. e.* leſs in Winter than in Summer; let *Fig.* 5. *Plate* the 26*th. prædict.* be a Glaſs wherein a Bell is hung as A, and opening the Cock that the Air in the Glaſs may have Communication with the external Air, let the Glaſs be ſhaked, and the Diſtance be determin'd when the Sound can be heard; warm the Glaſs and repeat the Experiment, and the Sound will be heard at a greater Diſtance.

IF was agreeable to this, that the Ancients had ſeveral Inſtruments of Muſick which ſounded when the Sun ſhined upon them; and *Cornelius Tacitus* in his Hiſtory maketh mention of ſuch a one in *Egypt*, and *Pauſanius* is ſaid to have ſeen the Figure. The Sound whereof was like the Strings of a Harp when they break.

De Caus, from whom this Invention is taken in *Plate* 9*th* and 10*th* of his forcible Movements by Water, *&c.* teaches the raiſing of Water in a Veſſel of Copper or Lead (by the Heat of the Sun) by means of the Valve at A. *vid. Plate* 27. *P.* 350. Now when the Water ſhall be in F, it ſhall be tranſported into C by the Siphon B, which caſting its Water into C, ſhall make the Air breathe forth of it, and animate the two Organ-Pipes, which with the Engine may be put into the Figure or Pedeſtal; or otherwiſe, if the Engine be put at a Diſtance, you muſt uſe Conveyances for the Wind, and ſo

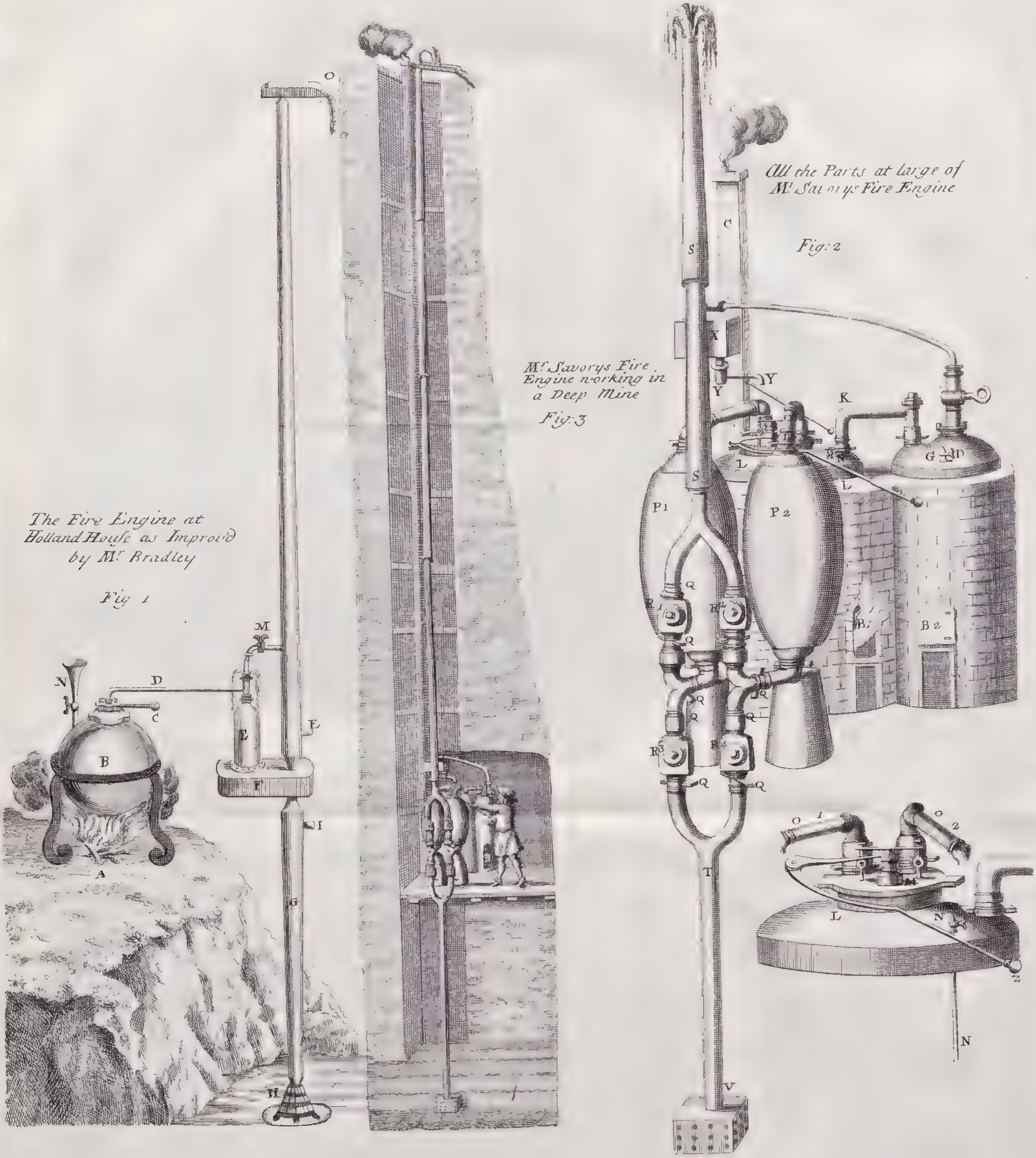
the Pipes only may be in the Figure, which being of Braſs, and hollow, ſhall have no Air but by the Mouth; by which the Sound of the Organ Pipes ſhall come forth.

NOW it is plain, that the Rarefaction of the Air, by the heating the Organ-Pipes by the Sun, as was before-mention'd; and the Methods by which this is effected will more plainly appear by *Fig.* 2. *Plate* 27*th*, *prædict.* of which take the following Account.

YOU muſt have four Veſſels of Copper well ſoldered round about; each of which ſhall be about a Foot ſquare and 8 or 9 Inches high, the Veſſels are mark'd with A B C and D, and there muſt be alſo a Pipe mark'd with E put upon the ſaid Veſſels, to which Pipe there ſhall be ſoldered four Branches, each Branch being mark'd with the Letter F, the ſaid Branches ſhall be ſoldered to the Top of the Veſſels, paſſing almoſt to the Bottom of each: Then there muſt be ſoldered a Sucker mark'd with G to the middle of the Pipe, made and plac'd ſo, that when the Water ſprings out of the Veſſel, it may open, and being gone forth, it may ſhut again.

THERE muſt be alſo another Pipe at the Bottom of the ſaid Veſſels mark'd with P, to which there is alſo four Branches, the which muſt be ſoldered againſt the Bottoms of the ſaid Veſſels, and alſo a Sucker mark'd H, to the end of which there is a Pipe which deſcends to the Bottom of the Water, the which ſhall be in a Ciſtern or Veſſel mark'd with I: There ſhall be alſo to one of the Veſſels a Hole or Vent mark'd within; ſo placing the Engine in a Place where the Sun may ſhine upon it, pour the Water into the Veſſels by the Hole or Vent M, which Water ſhall be communicated to all the Veſſels, by the means of the Pipe P: And the ſaid Veſſels muſt have about a third Part of their Content in Water; and the Air which was in the Place of the ſaid Veſſels ſhall paſs out by the Paſſages 3, 4, 5, 6; afterwards you muſt ſtop thoſe Paſſages very cloſe, ſo as the Air may not come out of the ſaid Veſſels; and then the Sun ſhining upon the ſaid Engine ſhall make an Expreſſion, becauſe the Heat which cauſeth the Water to riſe from all the Veſſels to the Pipe E, and paſs forth by the Sucker G, and the Pipe N, and then fall into the Baſon O, and from thence into the Ciſtern I; and when there ſhall be a great quantity of Water run forth by the Violence of the Heat of the Sun, then the Sucker G ſhall return; and after the Heat of the Day is paſs'd, and the Night ſhall come, the Veſſels ſhall draw the Water of the Ciſtern by the Pipe and Sucker H P, and ſhall fill the Veſſels as before; ſo as the Motion ſhall continue ſo long as there is Water in the Ciſtern, and that the Sun ſhines upon the Veſſels: And you muſt obſerve, that the two Suckers G and H muſt be made very light;

and



The Fire Engine at Holland House as Improv'd by Mr Bradley

Fig 1

Mr Savorys Fire Engine working in a Deep Mine

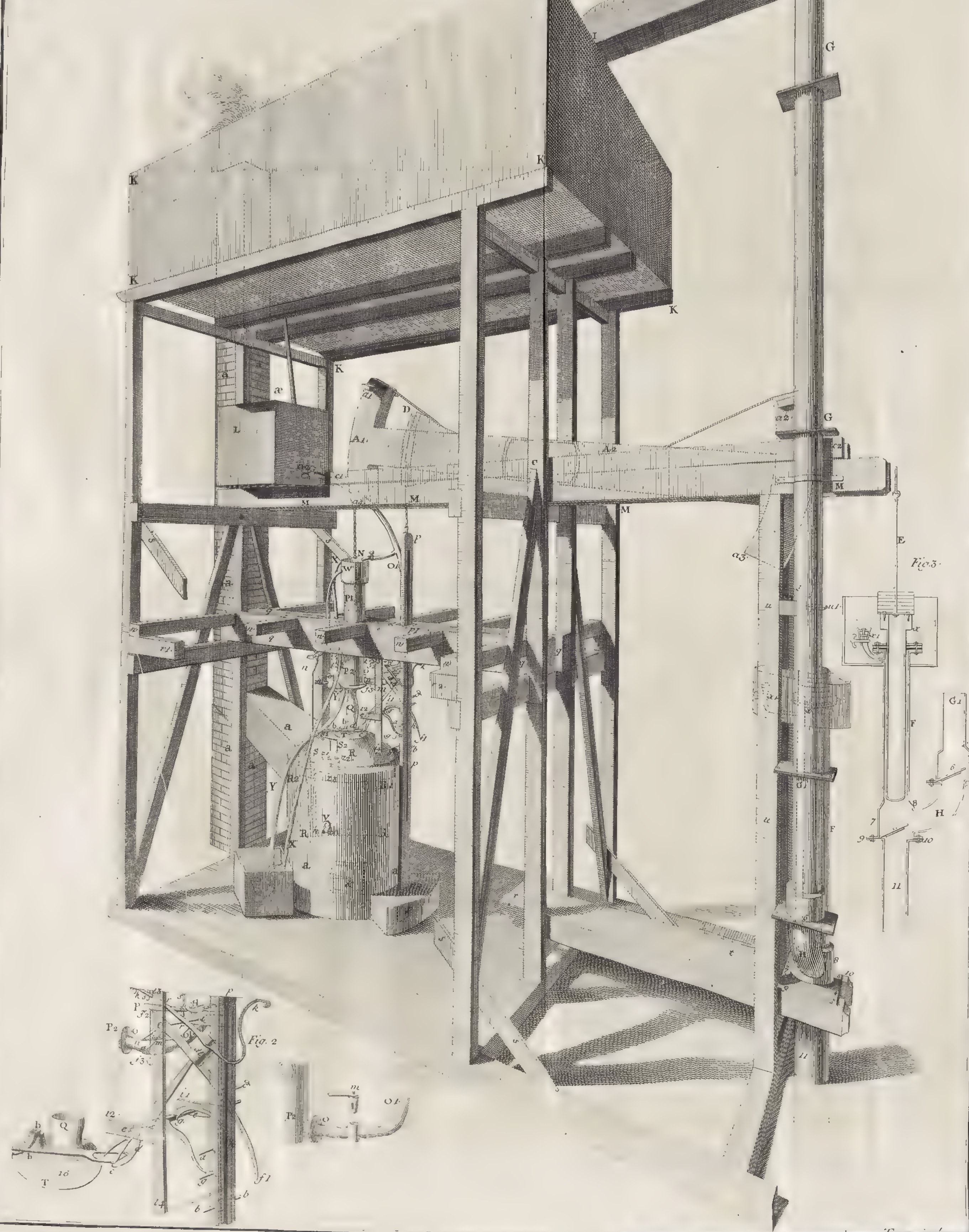
Fig: 3

All the Parts at large of Mr Savorys Fire Engine

Fig: 2

obferve, that the two Suckers [illegible] e

A DRAUGHT in PERSPECTIVE of an ENGINE for RAISEING WATER by FIRE.



Tome sculp.

and likewiſe very juſt, ſo as the Water may not deſcend by them when it is rais'd.

THE manner, by which the Hydraulick or Engine before mention'd, and its Effects, being thus explain'd, let us proceed to a curious Invention of *Hero Alexandrius*, which repreſents divers Birds, which ſhall ſing diverſely when an Owl turns towards them; and when the ſaid Owl turns back again, they ſhall ceaſe their Singing. *Vid. Plate* 28. *pag.* 35.

LET there be a Water-Wheel as A, which ſhall turn in a Caſe of Lead or Copper mark'd with C, which Caſe ſhall ſeem to keep the Water from ſcattering abroad and ſpoiling the Motion, and the Axle-tree of the ſaid Wheel ſhall reſt upon two round Holes, which ſhall be on the Sides of the ſaid Caſe, and at the one End of the ſaid Axle-tree which cometh thro' the ſaid Caſe: There ſhall be a Pinion of eight Teeth mark'd with D, which ſhall turn a Barrel of 12 or 15 Inches; alſo there muſt be three Conveyances for the Wind mark'd with E F G, to which there are ſoldered 3 Cocks, whereof the Keys are made as M O, to the end that when the Barrel turns the Pins Q and R, they may make the ſaid Conveyances open to let the Air into divers Whiſtles, the which ſhall make ſeveral different Tunes, according to the Fabrick of thoſe Whiſtles, and the Diſpoſition of the Pins and touches Q and R. And moreover, you may give a certain Motion to the Tails and Beaks of the Birds; if you put certain Strings to the Keys of the Cocks, as the Figure declares.

AS concerning the Motion of the Owl, which turns forwards and backwards in a certain ſpace of Time, it may be ſeen by the turning the Veſſel X, and the Leaver 3 and 4, where is the Counterpoiſe 8; for this Veſſel deſcends when full, and makes the Counterpoiſe to riſe, and the Pin of the Leaver ſtops the Barrel, by the Means of the Pin marked 6, which is at the End thereof; and ſo the Birds ceaſe their ſinging: Then when the Owl ſhall be towards them; and when the Veſſel X is void, ſhe ſhall turn again by the Means of the Counterpoiſe, and the Barrel ſhall begin to turn, as is demonſtrable by the Figure.

A pretty Conceit of this Kind, where a Bird is taught to whiſtle, by the Fall of Water, is in an ancient Grotto at *Ainſtone*, near the late Duke of *Shrewsbury*'s in *Oxfordſhire*, an Account of which you have in Dr. *Plott*'s Natural Hiſtory of that County, which was made to warble out its Sound by the Cadence of the Water; and innumerable other Inventions of that Kind might be contriv'd, too long for me to inſert in this Place.

The two laſt Machines I ſhall exhibit, are thoſe by which you may make a pair of Organs ſound by the Means of Water, and the other one, whereby Organs, or any other Trumpet-like Inſtrument or Inſtruments ſhall ſound, when the Sun ſhall be riſing towards its Meridian, without any other Principle of Motion, but the Heat of the Sun and the Water.

The Muſical Wheel mark'd A (*Plate* 29. *Page* 350) may be of 5 or 6 Foot Diameter, which ſhall be turn'd by a Pinion of eight Teeth, to the Axle-tree whereof there ſhall be fitted a Wheel of twenty four Teeth, which ſhall be turn'd upon a Pinion, on whoſe Axle-tree the Water-Wheel C is faſten'd; the Keys are mark'd with D, and the Place where the Pipes ariſe with E, and the Summer with F, the three Regiſters mark'd G H I, are different the one from the other. And to the intent that the Noiſe of the Motion may not be heard when the Pipes play, it is good that there be a Wall of a Foot thick between the Regiſters and the ſaid Motion; the Conveyances of the Wind are of Copper, which coming from the Summer to the Regiſters, paſs through the ſaid Walls.

The other Machine, (*vid. Plate* 30. *Page* 350) is a Veſſel of Copper or Lead mark'd A, very cloſe and ſolder'd on every Side, and let it have a Siphon mark'd with C, which may be ſo made, that the End which is in the Veſſel be near the Bottom, and that the Height of the ſaid Pipe or Siphon be near the Height of the ſaid Veſſel, then the other End ſhall come forth of the ſaid Veſſel, to run into the Veſſel D.

And to order it ſo, that the Sun may not heat the Veſſel A, till ſome determin'd Time about Mid-day, as you ſhall deſire, let there be a Tablet made to the ſaid Veſſel, of ſtrong Lead or Copper, mark'd with B (as if it were a Cover of the ſaid Veſſel half lifted up) but well ſolder'd thereto, and let the Veſſel be well environed with a ſmall Wall of Brick, ſo as there may be only the Side before open to the Sun, which Side ſhould be exactly plac'd towards the South.

It is certain, this being well done, that the Sun ſhall not ſhine againſt the ſaid Veſſel, but at Noon, or ſuch other determinate Time then abouts, as you ſhall deſire; and then the Rays ſhine againſt the Angle, which the Top of the Veſſel makes with the Table B, and by that Means heats the Top of the ſaid Veſſel, and which ſhall make a Compreſſion in the Veſſel, ſo as that the Water ſhall run forth by the Pipe C; let there be alſo a great Veſſel mark'd with F, into which the Water of the Spring or Pipe of Conduit, which

which is to make the Motion, runs continually, and at the Bottom of the ſaid Veſſel there is a Valve mark'd with G, at the lower End whereof, there is a Pipe with a Cock mark'd with H, which ſerves to temper the Courſe of Water which falls upon the Water Wheel which is below.

So when the Sun ſhall be any where near, or at the Meridian or Place, towards which you place the Box, his Rays ſhall ſhine againſt the Veſſel A, which ſhall cauſe a Compreſſion of the Water which is within, which ſhall run forth by the Pipe C, into the Veſſel D, which being half ſhut, ſhall deſcend and open the Valve G, which being open, the Water of the Veſſel F ſhall run upon the Water Wheel, and make the Muſick Barrel turn, as hath been before ſhewn; and the Pins that are put upon the ſaid Barrel, ſhall touch the Keys M, which being put down, ſhall open the Valves which are under the Summer X; and the Wind that ſhall be in the ſaid Summer, ſhall make the Pipes of the Organs or Trumpets ſound, which are above the Summer. Now Wind may be given to the ſaid Summer, after two ſeveral Manners; that is to ſay, by a Reſerve, which is fill'd with the Water which falls upon the Water Wheel, or by Bellows, which are raiſed by another Water-Wheel, which ſhall move when the Veſſel D deſcends, and ſhall open alſo a Valve, as that which is mark'd with G: But becauſe the Muſick Inſtrument muſt ſtop juſt at the Point where it began (when the Muſick Barrel hath made one Turn) to the end, that when it begins to ſound another Tune, the Muſick may be of a juſt Meaſure.

Now, to make it ſtop, you ſhall make a ſmall Veſſel of Copper mark'd with E, which ſhall have a ſmall Hole at Bottom, and ſhall be ſo placed, that the Cord which holds it ſhall be faſtened to a Ring near the Valve G, and the Water which ſhall fill the ſaid Veſſel, ſhall be conveyed by the Pipe mark'd with L; ſo as when the Valve G is opened, forthwith the Water ſhall run into the ſaid Veſſel; and when the Water of the Veſſel F ſhall be a little abated, then it ſhall run no more into the Veſſel E, which ſhall always empty the Water which is in it by the ſmall Hole at the Bottom; and the Time that the ſaid Veſſel E empties, muſt be fitted to the Time which the Wheel requires to make one Turn; and the ſaid Veſſel being empty, the Valve G ſhall fall down again, becauſe it ought to be made in a manner heavier than the two Veſſels C and D when they are empty: And on the contrary, when one of the ſaid Veſſels is full, that they may be heavier than the ſaid Valve: And as concerning the Veſſel D, it is neceſſary that it empties rather than E; becauſe it need not keep ſo exact a Meaſure as E.

And here may be ſeen likewiſe how it empties when it is half full of the Water which deſcends by the Pipe C, then it draws down itſelf, and that mark'd with E alſo; becauſe it is heavier than G at the ſame Inſtant that G opens, and the Water deſcends upon the Wheel, and into the two Veſſels; and when D is full, then the Veſſel turns the Top downwards and empties; and in the ſame Time the Water of the Veſſel F abates, and is lower than the Height of the Pipe at D, the Water ſhall run in no more, but the End of the Pipe L muſt be ſomething lower than that of D, to the end that the Water may there run longer: It now remains to ſhew how the Pipe A is fill'd again with Water.

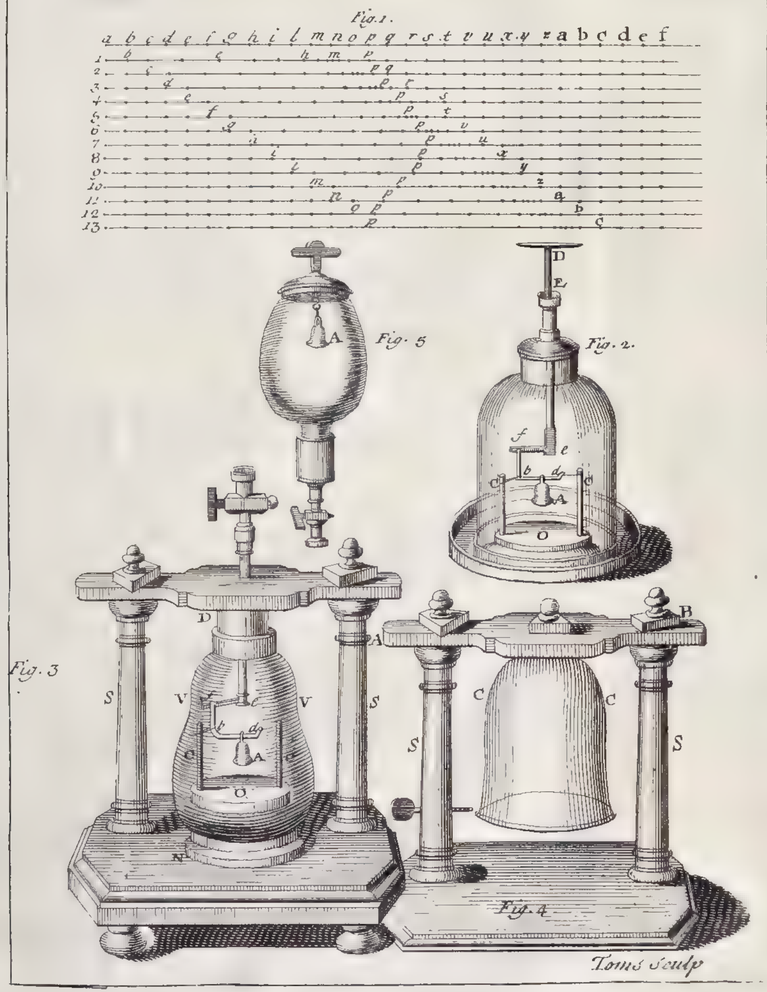
Therefore let there be a Pipe put with a ſmall Valve under the ſaid Veſſel; and after that the Heat of the Sun has made the Compreſſion, and that one Part of the Water of the ſaid Veſſel ſhall be run out after the Sun has paſſed the ſaid Veſſel, to fill again by the Valve, as has been before taught.

What I have to add more to this Chapter, is to acquaint my Reader, that what I have laid down before, is taken either verbatim from *De Caus*, and other curious Authors, who have wrote on this Subject, and to introduce a Deſign, which I am told is in great Eſteem in *Italy*, I mean the Organ, which is play'd by a Water Fall from the Top of a high Rock, (*Vid. Plate* 59. or 60. *Page* 352) which is, I think, in the Gardens of the Family of *Eſte* at *Tivoli*, leaving this ſo curious a Piece of Hydraulicks to the further Improvement of the Gentlemen whoſe Genius's lead them to the Seraphick Entertainments of Muſick; in which I muſt own my ſelf not well acquainted.

The End of the Third BOOK.

NOTES

Plate 26 Pa: 352



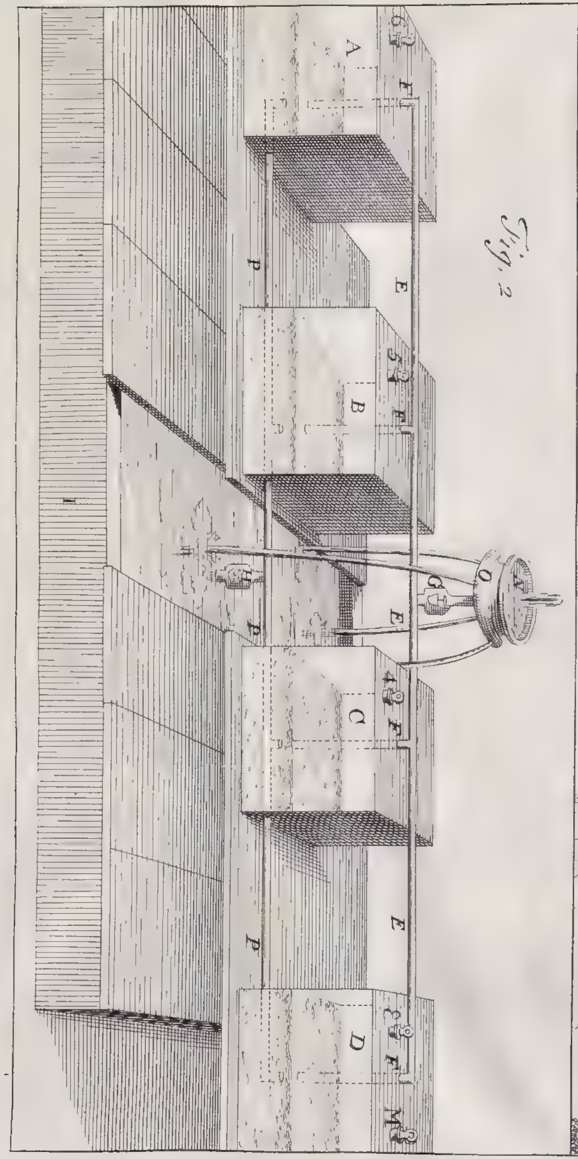


Fig. 2

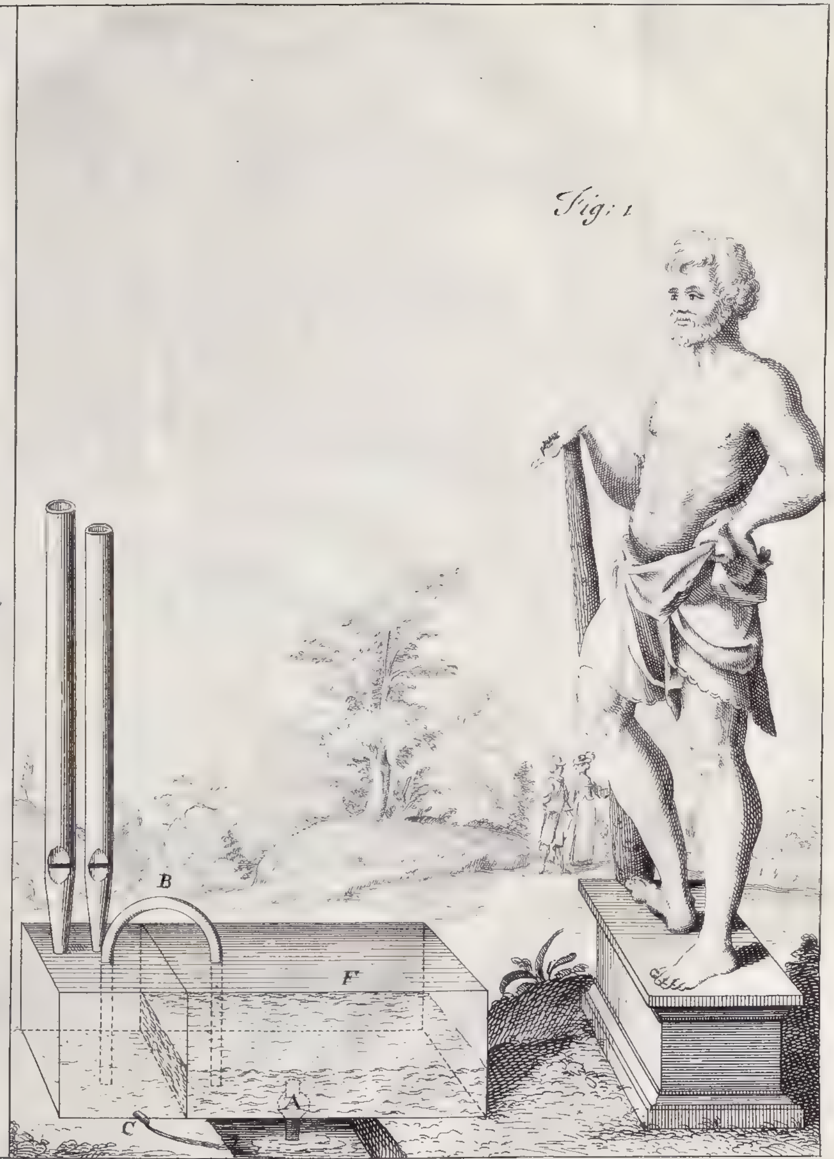
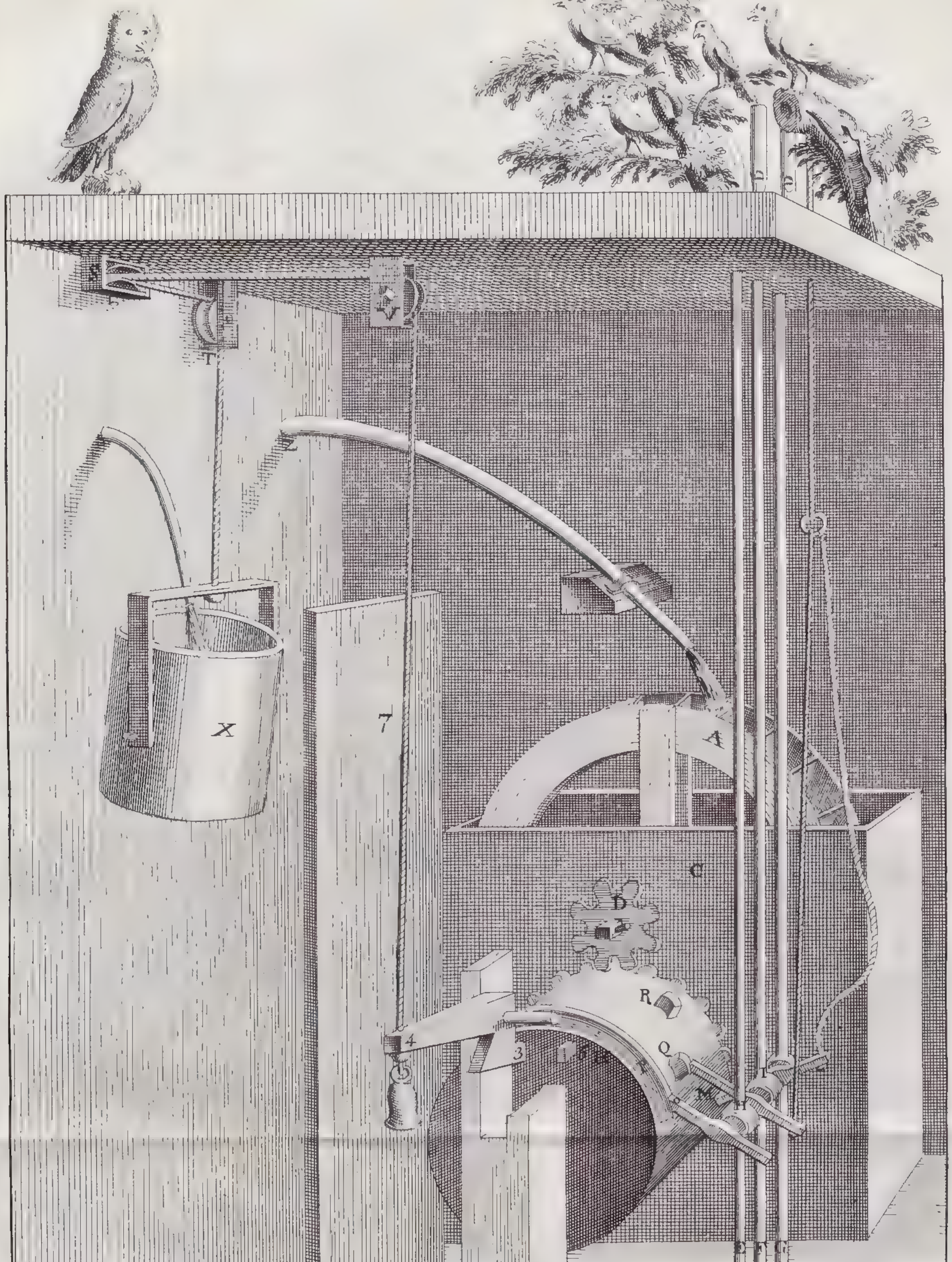
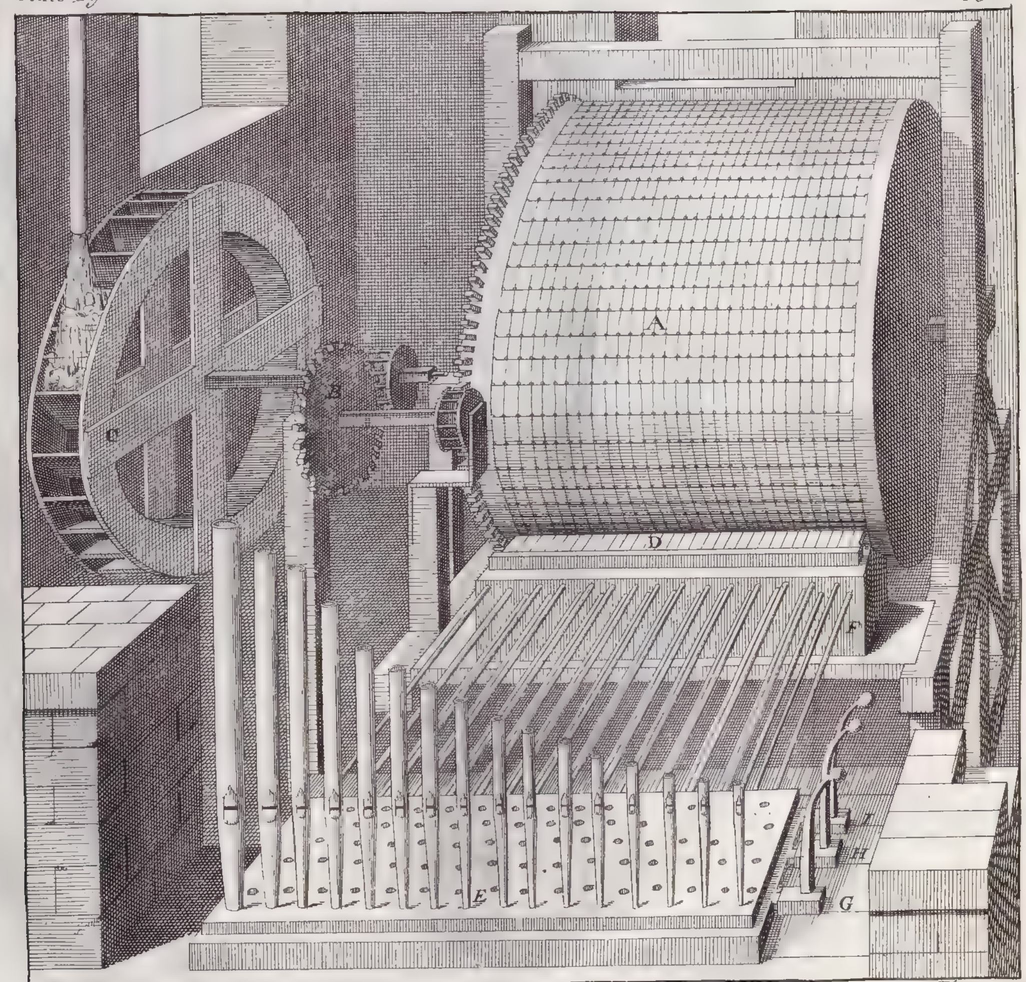


Fig: 1

Toms Sculp

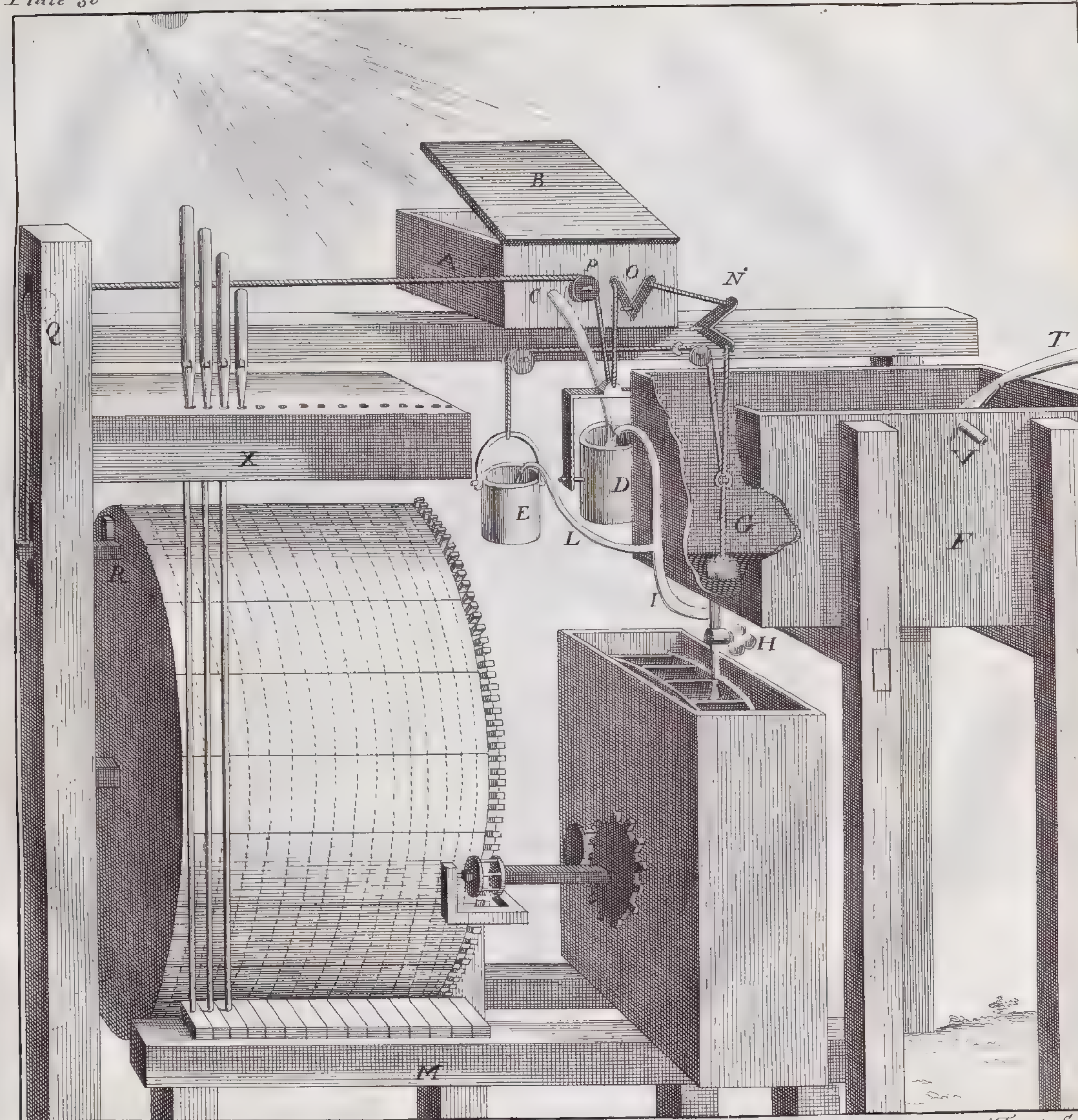


Toms sculp



Toms sculp

Plate 30



Toms Sculpt

III. Pumps which may be work'd by one Man, for raiſing Water out of any Well, upwards of 120 Feet deep, ſufficient for the Service of any private Houſe or Family, and ſo contrived that by turning a Cock, may ſupply a Ciſtern at the Top of the Houſe, or a bathing Veſſel in any Room; and by ſcrewing a Leather Pipe the Water may be convey'd either up Stairs, or in at a Window, in Caſe of any Fire.

IV. All manner of Fancies in Fountains.

Specimens now in Practice, *viz. One made for Mr.* Moſes Hart *at* Iſleworth, *whereby* 85 *Barrels of Water in about the Space of half an Hour are thrown into a Ciſtern to the Top of his Houſe in a conſtant Stream, and with great Velocity, from a River* 540 *Feet diſtant, and about* 40 *Feet perpendicular. Another at* Deptford, *for the Service of a* Diſtil-Houſe *near the* King's Yard, *which will raiſe* 150 *Barrels of Water in leſs than an Hour, about* 30 *Feet perpendicular, with the like Stream and Force, and at the ſame Time (as Occaſion requires) does the Office of another* Engine *to raiſe* Waſh and Worts *conſiderably higher*; *both* Engines *are performed with Eaſe by one Horſe.*

Alſo another made for Eſquire Savill, *near Sir* John Eyles *at* Rumford, *worked by two Men, that raiſes Water in the ſame conſtant Manner, through a Bore near two Inches Diameter,* 360 *Yards Diſtance, and* 42 *Feet perpendicular. With ſeveral other uſeful Engines, too tedious to mention.*

The Encouragement given by the Honourable Board *of His Majeſty's* Victualling-Office, South-Sea-Company, *and other* Honourable Perſons, *preferring their* Fire-Engines *to any others; and the Satisfaction given to the Gentlemen before mentioned, ſufficiently ſhews their* Excellency. *And for the Satisfaction of any who ſhall be deſirous of having* Engines *for the Services aforeſaid, by ſending a Line to Mr.* Fowke *in* Nightingale Lane, Wapping, *ſuch Perſon ſhall be attended and made ſenſible, whether what he intends to have performed is feaſible, before he is at any Expence.*

Sizes.	Gallons of Water delivered in a Minute.	At what Number of Yards diſtant.	Prices with ſucking Pipes.	40 Feet of Leather Pipes, with a Pair of Braſs-Screws.		
			l.	*l.*	*s.*	*d.*
1ſt.	40	27	14	02	12	06
2d.	50	31	20	20	16	00
3d.	70	36	30	03	6	00
4th.	100	40	40	03	15	00
5th.	160	43	50	04	4	00
6th.	180	45	60	04	10	00

The next Artiſt's Account I produce, is that of Mr. *Richard Newſham* of *Cloth Fair*, who makes the moſt uſeful, ſubſtantial, and convenient Engines for quenching Fires, *&c.*

Richard Newſham of *Cloth-Fair, London*, Engineer,

MAKES the moſt *uſeful, ſubſtantial*, and *convenient Engines* for quenching Fires, which carries continual Streams with great Force. He hath play'd ſeveral of them before his Majeſty, and the Nobility at St. *James*'s, with ſo general an Approbation, that the largeſt was at the ſame time ordered for the Uſe of that Royal Palace: And as a further Encouragement (to prevent others from making the ſame Sort, or any *Imitation* thereof) his Majeſty has ſince been graciouſly pleas'd to grant him his *ſecond* Letters Patent, for the better ſecuring his Property in *this*, and ſeveral *other Inventions* for raiſing Water from *any* Depth, to any Height required.

THE *largeſt* Engine will go through a Paſſage about three Foot wide, in compleate working Order, without taking off, or putting on any thing: *And may be worked with ten Men in the ſaid Paſſage.* One Man can quickly, and with Eaſe, move the *largeſt Size* about, in the Compaſs it ſtands in: And is to be play'd without rocking, upon any uneven Ground, with Hands and Feet, or Hands only, which cannot be parallel'd by any *other Sort* whatſoever. There is *Conveniency* for above 20 Men to apply their *full Strength*, and yet reſerve both Ends of the *Ciſtern clear* from Incumbrance, that *others* at the ſame time may be pouring in *Water, which drains through large Copper Strainers.* The Staves that are fixed through the Leavers, along the *Sides* of the Engine, for the Men to work by, *though very light*, as alternate Motions with *quick Returns* require; *yet* will not *ſpring and loſe Time the leaſt*: But the *Staves of ſuch Engines as are wrought at the Ends of the Ciſtern, will ſpring* or *break*, if they be of ſuch a *Length* as is neceſſary for a large *Engine, when* a conſiderable Power is apply'd: And cannot be fix'd faſt, becauſe they muſt at *all Times* be taken out, before *That Engine* can go through a Paſſage. The playing *two Streams* at once, do neither iſſue a greater Quantity of Water, nor is it *new, or ſo uſeful*, there having been of the *like Sort* at the *Steel-yard*, and *other* Places, 30 or 40 Years; and the Water being *divided*, the Diſtance and Force are accordingly *leſſen'd* thereby: *That Way* of working not becoming *more publick*, is a viſible Proof, that *it* doth not *anſwer*; *for with a very ſmall Addition, any Engine will do the ſame.*

THERE is a Miſtake very common among *ſuch* as are not well acquainted with the *Laws of Nature*, and the Effects of *Mechanical Powers, who* imagine, that the more Purchaſe the Leavers have upon the *Forcers* in the *Barrels (without any Regard to Time)* the *greater* the Performance, *both as to Length of the Stream, and Quantity of Water deliver'd*; but 'tis *well known, that Notion* is wrong; for the greater the Purchaſe is, *by applying the operating* Power, *more diſtant from the Centre*, the *ſlower* will the Motion of the *Forcers* be; which is *conſiſtent with all Mechanical Effects*; *thus*, What is gain'd by *the Power*, is loſt in *Time*.

THOSE who *pretend* to make the *Forcers* work in the *Barrels*, with a *perpendicular* Stroke, without Rack, Wheels, Chains, Crank, Pully, *or* the like, by *any kind of contrived* Leavers, or *circular* Motion whatſoever, with *leſs Friction*, than if *guided* and *work'd* by *Wheel* and *Chains*, (*which of all Methods is the beſt*,) do only *diſcover their Ignorance*; *they* may as reaſonably *argue*, that a great *Weight* can be dragg'd upon a Sledge, with as little *Strength*, as if drawn upon Wheels.

THE approv'd *Duration* of thoſe *Chains* both from Water and Ruſt, has been ſufficiently experienc'd for ſome Years, in ſeveral Parts of this and other Kingdoms; *but to inſtance ſome Places at Home*, particularly at the *Hand-in-Hand*, and other *Aſſurance Offices*, whoſe Buſineſs it is to be firſt and laſt at *every* Fire that happens in

the Cities of *London* and *Weſtminſter*, and the *Suburbs* thereof; who *conſequently* with much uſing, muſt have throughly tried them. As to the *Treddles*, on which the Men work with their Feet, there is *no* Method ſo *powerful*, with the like *Velocity or Quickneſs*, and more *natural* and *ſafe* for the Men: *Great Attempts* have been made to exceed, but *none* yet could *equal this* Sort; the fifth Size of which hath play'd *above* the Graſhopper upon the *Royal Exchange*; which is upwards of 55 Yards high, *and this in the Preſence of many thouſand Spectators.*

Thoſe with Suction feed themſelves with *Water* from a *Canal*, *Pond*, *Well*, &c. or out of their own *Ciſterns*, by the Turn of a *Cock*, without interrupting the *Stream*. They are far leſs liable to *Diſorder*, much more *durable* in all their Parts, than any extant, and play off large Quantities of Water at the Diſtances under-mentioned, either from the Engine, or a Leather Pipe, or Pipes of any Length requir'd; (*the Screws all fitting each other*) *This* the *cumberſome ſquirting-Engines*, which take up *four* times more Room, cannot perform; neither do they throw one fourth Part of their Water in the Fire, at the like Diſtances, but *loſe* it by the Way; nor can they uſe *Leather-Pipe* with them to *much* Advantage, whatever Neceſſity there may be for it.

The five large Sizes go upon Wheels, well box'd with *Braſs*, fitted to ſtrong *Iron* Axles, and the other is to be carried like a Chair. ——Their *Performances* are as follow, and the *Prices* fix'd ſo, *as to induce* the Nobility, the Commons, Cities, Boroughs, Corporations, Towns, Colleges, Hoſpitals, Companies-Halls, Pariſhes, the Gentry, and others, who have not furniſhed themſelves therewith, to become acquainted with this uſeful *Invention*, for their Defence againſt deſolating Fires.

These Engines will alſo, by putting the *Fan* upon the *Branch*, water Gardens like unto Rain.

He makes ſome *ſmaller* Engines, from 6 *l.* to 17. *l.* Value, and *Machines* for *emptying Ponds* to raiſe *Water*, *Hot-Worts*, &c. and Water-Works for any Purpoſe, to be work'd by *Water*, *Horſe*, or *Man*; or by Wind, on a *conſtant Speed*, tho' it blow *unequally*, which of *themſelves* always keep *their Sails* to the Wind: Alſo *Fountains*, that will play *Columns* of Water 4 *Inches Diameter*, 40 *Foot high*, with one 10th Part of the Water, and *Power* to force it, as is required in *other* Jets of the *like Size* and *Height*.

Number of Sizes.	What Quantity of Water the Ciſterns hold in Gallons.	Quantity diſcharged *per* Minute in Gallons.	At what Number of Yards Diſtance.	Price without Suction.	Price with Suction, and 6 Foot of Sucking-Pipe included.	Price of the Leather-Pipes, each Pipe 40 Foot long, with a Pair of Braſs Screws included.	
1ſt.	40	60	33	17 *l.*	20 *l.*	2 *l.*	18 *s.*
2d.	75	75	35	26	30	3	3
3d.	95	100	40	30	35	3	5
4th.	125	125	45	35	40	3	7
5th.	176	160	48	45	50	3	17
6th.	185	190	50	55	60	5	

POST-

POSTSCRIPT *by way of* Notes *on* Book III. *relating to the Rising of Water in Pumps.*

To compleat this Collection of Hydraulicks, I add, by way of Postscript, an Observation which I have long made concerning the Practitioners in the Art of Pump-work, who differ very largely from each other in their Opinion, relating to the proper Length or Fall of Pistons in Pumps; those who are for making the Stroke long, *viz.* 3, 4, or 5 Foot, or sometimes more, urge the Necessity there is to force up large Quantities of Water to great Heights, and say, that if there is not such a Thrust, the Water will recede backwards again, and not rise up with that Uniformity which is requisite in Works that go continually; but others are of a different Opinion, and, amongst them, Mr. *Newsham* of *Cloth-Fair* tells us in his printed Proposals, That *what is got in Purchase is lost in Time*; and indeed I cannot but be of the same Opinion as this laborious Engineer is of, and think, that where there are 3 or 4 Leavers constantly at Work, there is no Occasion for long Strokes, unless it be where there is only a single Piston, as is in the *York-Buildings* Engine; and there indeed a 6 Foot Stroke is necessary, in order to the giving the Water in the Pipes its full Force.

Mariotte, *Page* 105. of his *Hydrostaticks* (*English* Edition) makes use of an Algebraical Calculation for the raising of Water in the following Manner. Suppose, (says he) the Barrel to be 12 Foot above the Surface of the Water, that you would raise; and suppose that you have a mind to raise it to this Height of 12 Foot by one Stroke of the Piston, you must make this Analogy: As 20, the Complement of 12 Foot, is to 32; so is 12 Foot of common Air to a 4th Proportional; this 4th Proportional will be 19 $\frac{1}{5}$, which shews that the Barrel of the Pump must be pretty long to raise the Piston 19 Foot $\frac{1}{5}$ above the 12 Foot, in order to raise the Water 12 Foot, by only one Stroke of the Piston; but if the Play or Stroke of the Piston were limited to 2 Foot, you must say; As 32—A is to 32, so is 12—A to 14—A. The first Term is the Complement of the unknown Height to which the Water will rise, to 32 Foot of Water; which is the Weight of the Atmosphere: The third Term is the 12 Foot *minus* that Height, and the Fourth is the 2 Foot that the Piston rises, join'd to 12 Foot *minus* the same Height. Now the Product of 14 — A, by 32 — A, is 448 — 46 A + A A, and the Product of the two middle Terms is 384 — 32 A; the Equation being reduc'd, there will be an Equality betwixt A A and 14 A — 64; and because 64 cannot be taken from 49 the Square of 7, which is half the Roots, 'tis a Sign, that in continuing to pump, at several times you may raise the Water up to the Piston; and to know how far it will rise the first Stroke, you must suppose that the Piston is risen 2 Foot; there will be an uniform Barrel of 14 Foot; and according to the Rules laid down in his Essay upon Logick, and his Treatise of the Nature of Air, which makes this Calculation. The enclos'd Air was 12 Foot; 12 Foot + A is to A, as 32 to 2 — A; the Equation being reduc'd, you will find that A A will be equal to 24 — 42 A; and at last, that the Value of the Root will be a little less than $\frac{4}{7}$; which being taken from 2, there will remain 1 $\frac{3}{7}$ and a little more; and consequently the Water will by the first Stroke of the Piston rise but one Foot $\frac{3}{7}$, and a little more.

If you had suppos'd the Play of the Piston to be one Foot, you might know by the same Calculation how high the Water would rise by the first Stroke of the Piston; and if you would know to what Height it may rise after several Strokes, you must say, As 32 — A is to 32, so 12 — A is to 13 — A; the Equation being reduc'd, you will find 13 A — 32 equal

to A A. The Square of 6 $\frac{1}{2}$ the Half of the Root is 42 $\frac{1}{4}$; from which ſubſtracting 32, there remains 10 $\frac{1}{4}$, the Root of which is 3 $\frac{5}{24}$ a little leſs: Take that from 6 $\frac{1}{2}$, and there remains 3 and $\frac{7}{24}$; add that to 6 $\frac{1}{2}$, and it will make 9 $\frac{12}{24}$; and theſe 3 $\frac{7}{24}$ and $\frac{19}{24}$ will be the two Roots; which ſhews that the Water can never riſe when the Barrel is empty, above 3 foot $\frac{7}{24}$ and a little more, tho' you play the Piſton as long as you pleaſe; but if you had fill'd the Barrel 9 Foot $\frac{18}{24}$, you might make the Water riſe 12 Foot compleat by ſeveral Strokes of the Piſton.

Let us ſuppoſe now that the Barrel is 14 Foot up to the Piſton, and that the Stroke of the Piſton is 2 Foot; 32 — A will be to 32, as 14 — A to 16 — A. To find the Equation eaſily, you muſt multiply 32 by 2, the Difference of 14 and 16: The Product is 64 for the abſolute Number, and that of 16 A, will be the Number of the Roots, and A A will be equal to 16 A — 64; the Square of half the Root is 64; from whence ſubtracting 64, there remains 0, whoſe Root is 0, which being taken from and added to 8, ſtill makes 8; which ſhews that there is but one Root, and that the Water can't riſe above 8 Foot; but if you make the Piſton play ever ſo little higher than 2 Foot, the Water will riſe 14 Foot. The Analogy is eaſy; for the Piſton being raiſed 2 Foot, the Barrel will be 16 Foot, and that Water being at 8 Foot, there will remain 6 Foot of Air; but 32 is to 24 the Complement of 8 Foot to 32, as 8 Foot of rarified Air to 6 Foot of common Air; then the Water will raiſe no higher than 8 Foot, if the Piſton plays but 2 Foot.

Thence you ſee, that to draw up Water to a conſiderable Height, as 20 Foot, the Breadth of the Pump-Barrel muſt be diminiſh'd, and a ſufficient Space muſt be allow'd for the Stroke of the Piſton; for, ſuppoſing that the Surface of the Piſton be 4 times broader than the Baſe of the Barrel, the riſing of the Piſton 1 Foot, will have the ſame Effect as if it roſe 4, if the Diameter of the Piſton were only equal to that of the Barrel; if then the Srroke be a Foot and a half, it will be the ſame as if it roſe 6 Foot, and were of the ſame Breadth: Now the 4 Terms of Equation being 32 — A; 32, 20 — A, 26 — A, there will be 6 times 32, *viz.* 192 for one Term of the Equation, and 26 A for the other, according to what has been ſaid; there will be then A A equal to 26 A — 192; the Square of half the Roots is 169 leſs than 192; and conſequently if you pump a long time, you may raiſe the Water 20 Foot.

If in the Example above-mention'd, you take 8 Foot for the higheſt Term of the Water, when the Barrel is 14 Foot, and the Stroke of the Piſton 2 Foot, 'tis eaſy to prove, that if you ſuppoſe 9 Foot of Water upon the Clack, it will continue to riſe by the playing of the Piſton 2 Foot; for there will remain 5 Foot of Air. Now there is a leſs Proportion betwixt 5 and 7, than there is betwixt 27, the Complement of 5 to 32, and 32, and conſequently the Water will riſe higher than 9 Foot The Proportion will ſtill be more unequal, if you take 10 or 11 Foot; and if you take 7 inſtead of 8 Foot, the Water will ſtill riſe, for there will remain 7 Foot of Air; now 25, the Complement of 7 to 32, is to 32 as 7 to 8 $\frac{24}{25}$; then if the Piſton goes 2 Foot, it will raiſe the Water higher than 7 Foot; it will riſe ſtill more eaſily, if you pour in only 6 Foot of Water; for there will be 8 Foot of Air. Now the Complement 26 is to 32 as 8 to 9 $\frac{22}{26}$; then if inſtead of 9 $\frac{22}{26}$, which makes the *Equilibrium*, the Piſton goes 10 Foot, it will make the Water riſe ſtill better than when it was at 7 Foot; and better ſtill than when it is at 5 Foot, *&c.* If you would know what Play the Piſton muſt have to raiſe the Water 30 Foot, you muſt take a Number a little greater than the half of 30, as 16, at which Point pretty near the Water, will riſe with the greateſt Difficulty; the Complement is 16, the Remainder of Air is 14; as 16 is to 32, ſo is 14 to 28. The Piſton then muſt riſe 14 Foot; or if the Barrel be 2 Inches Diameter, the Piſton muſt be 7 Inches $\frac{1}{2}$; for the Square of 7 $\frac{1}{2}$ is 56 $\frac{1}{4}$, which is a little more than 14 times 4 the Square of 2 Inches; and then it will be ſufficient that the Stroke of the Piſton be one Foot; but as it is ſtill more difficult at an Elevation of 18 Foot, the Piſton muſt be 8 Inches Diameter, to raiſe the Water above 18 Foot, when its Stroke is but one Foot.

AN

INTRODUCTION

TO A

General SYSTEM

OF

HYDROSTATICKS and HYDRAULICKS.

BOOK IV.

CHAP. XXX.

A General Introduction concerning the Coming-in of Water from Engines, or Springs, and the Expence thereof in Caſcades and Fountains.

IT highly behoves all Perſons that would have their Waterworks to ſucceed well, to make the exacteſt Calculations they poſſibly can, what Water their Engine or Spring will ſupply them withal; that ſo they may regulate the Extent of their Pipes of Conduct, Sheets, and Jets of Water, *&c.* ſince it would be a great Diſſatisfaction and

Reproach to the Owner of any Waterworks to have fine Grotto-Work, Caſcades, and other Inventions of this Kind, and not to have Water to ſupply them withal.

BUT by this Supply I would not be underſtood to mean a continual Cadence or Current of Water, that being to be had but in few Places, except on low Grounds, where Rivers, at leaſt Rivulets, have their Courſe: Nor can I readily ſubſcribe to thoſe that value no Caſcade or Fountain, except they play continually, ſince that would be limiting Waterworks to a few Places only, and would be the debarring many a pleaſant Situation of that which is one of the greateſt Beauties of it; I mean that of fine Water, eſpecially if to it be added the Cadence and Murmuring of Streams, in Grotto, Rock, Caſcade, and Fountain-Works, which, tho' they do not play always, yet have their proper Times of Diverſion, in all hot and ſultry Weather, and in the Lawns and other intermediate Spaces of Woods, Groves, and other Places of Delight; and the Experience we daily have of the vaſt Quantities of Water that good Engines produce, (which when emptied into Reſervoirs or Ponds, well clay'd, afford ſurprizing Quantities of Water, enough to ſupply not only Cities and Towns, but alſo large Baſons of Water,) confirm what I offer on this Head.

NOW, for the better underſtanding this Art, it will be requiſite that the Owner and Projector be rightly inform'd how many Inches of Water his Engine or Spring will give in a Minute, or an Hour, and conſequently how great a Quantity in twenty four Hours; that ſo he may compute how wide his Caſcades, Fountains, or his other Expences of Water that are required may be, and how long the Supply that arrives in twenty four Hours will play: One or two Hours, at moſt, in a Day, is generally ſuppoſed ſufficient; and for the Thickneſs of Water over a Caſcade, half an Inch is enough; and from Preliminaries ſo eſtabliſhed, may alſo be readily calculated, how much ſuch Caſcades may be contracted and enlarged. To proceed to the Theory or Motion of Spouting Water, &c.

THE learned *Graveſende*, *Book* II. *Part* 2. *Cap.* 8. of his *Mathematical Elements of Natural Philoſophy*, ſays, That *a Liquid ſpouting vertically out of a Hole*, ariſes up with that Celerity, with which *it would come up to the upper Surface of the Liquid, yet it never comes up to that Height:* Becauſe the Velocity of a Liquid increaſes, when the Depth of the Hole below the Surface of the Liquid increaſes, in the ſame Ratio as the Celerity of the falling Body increaſes, when the Space gone through by the Fall increaſes; and it is remarkable, that in the Beginning their Velocities are equal;

for

for in a Liquid the upper Parts, as well as thoſe in a Body, endeavour to deſcend by Gravity only.

Now the Celerity by which a Liquid aſcends is diminiſh'd every Moment, and the Column of the ſpouting Liquid conſiſts of Parts, which are moved to different Heights by different Celerities: All the Parts of a Column, which is every where of the ſame Thickneſs, are neceſſarily moved with the ſame Celerity; the ſaid Column will be every where broader every Moment, as the Celerity of the Liquid is diminiſh'd, which ariſes from the Impulſe of the Liquid following, and which, from the Nature of a Liquid, yields to every Impreſſion, and is eaſily moved every Way; and by that Impreſſion the Motion is retarded every where.

Secondly, This Motion is alſo diminiſh'd by the Liquid, becauſe when it has loſt all its Motion, it is hang'd up in the upper Part of the Column, and is ſuſtained for a Moment by the Liquid that follows it, before it flows off on the Sides, which retards the Liquid that follows it, and that Retardation is communicated to the whole Column.

Thirdly, This Motion of the Liquid is alſo diminiſh'd by the Friction that is againſt the Sides of the Hole, which Friction is increaſed when the Liquid is brought through Pipes and Cocks: And, *laſtly*, the Reſiſtance of the Air ſtops the Motion of all Liquids; the firſt Cauſe cannot be corrected, but the ſecond may, by ſomewhat inclining the Direction of the Liquid, (as by laying the Pipe on a Slope,) becauſe every Liquid riſes higher, and conſequently gives more Water, if it be a little inclined, than if it ſpouts vertically. This Celerity, and conſequently the Quantity of this Water, is likewiſe expedited by the Height of the Reſervoir (or Impulſe and Force of the Engine) from which it proceeds, as well as from the Largeneſs of the Apertures or Holes of the Adjutages and Pipes of Conduct, to which they are faſtened, which cauſes the Water-Spouts to go the quicker; and the Expence of Water through the ſame Paſſage is according to the Proportion of the Celerity or Velocity (call it which you will) it has in flowing out; and this Expence (as *Marriotte* ſets down, *Diſcourſe* III. *Page* 172.) is according to the duplicate Ratio of the Diameters of the Holes, which he has demonſtrated in the following Manner.

A B (*Fig.* 1. *Plate* V.) is a Plane with a round Hole bor'd in at *e f*; C D is another Plane bor'd with another Hole, though leſs, at *g h*; I L is a Cylinder paſſing through the Hole *e f* in a certain Time, as in two Seconds, according to an uniform Velocity; M N is another Cylinder of the ſame Length, but the Baſe much leſs,

 which

which alſo paſſes entirely through the Hole *g h* in two Seconds. It is manifeſt, that if the Diameter E F of the Cylinder I L, which is equal to that of the Hole, be double the Diameter of *g h*, the great Cylinder will be four Times as big as the other, ſince they are to one another as their Baſes, each of which is ſuppoſed to be equal to the Hole through which they paſs: Now ſince they have the ſame Velocity, when the half of the great Cylinder is paſſed through, the half of the little one will alſo be gone through; and that which has paſſed of one and the other, will be always in the ſame Proportion of 4 to 1: Then if we ſuppoſe theſe Cylinders to be Water-Spouts that have the ſame Velocity, there will always ſpout four Times as much Water from the great Hole as from the little one, which is in a duplicate Proportion of the Diameters of the Holes; and juſt ſo in reſpect of other Proportions.

From which Maxim he draws the two following Experiments:

Firſt, That a Reſervatory, or Ciſtern, 12 Foot 4 Inches deep, yielded through an Hole, exactly of 3 Lines Diameter, 14 Pints in 61 Seconds and a half; or, in other Words, in one Minute, one Second and a half, if continually kept full, that the Height of Water might preſs upon it; and though exactly of 6 Lines, it will yield the ſame Quantity in 15 Seconds and a half, which is almoſt according to the duplicate Proportion of the Diameter; for it would have yielded 56 Pints and a half in about the Time of 62 Seconds.

Secondly, That a Reſervatory of 24 Foot 5 Inches deep yielded through the ſame Hole of 3 Lines 14 Pints in 44 Seconds and a half; and in another Time in 45; and the Hole of 6 Lines yielded the ſame Quantity in 11 and almoſt 1 quarter; and having repeated the Experiment, it yielded it in 12 Minutes preciſely.

From whence, as well as from innumerable other Experiments that might be produced, it appears, that the Expence of Water coming into, or going out from one Reſervoir to another of equal Height, is in a duplicate Ratio of the Diameter of the Holes, the Diameter lying about ſeven Lines below the Surface of the Water; but when the Heights of the Water in the Reſervoirs are different, the higheſt give more than the others in a ſubduplicate Ratio of the Heights, that is, as the leaſt Height to the mean Proportional betwixt it and the great Height.

Torricelli, in his Treatiſe of the Motion of Water, (as *Marriotte* ſets down, *pag.* 180.) has given a Demonſtration, which ſeems *apropos* to the preſent Purpoſe; when he ſays, That if a Reſervatory A B C D, has a little Hole of four or five Lines at the Bottom at E, (*Fig.* 72. *Plate* 5.) and the Water being at the Height of the Line A B,

A B, may run out in 10 Minutes without pouring in any more, in its Defcent it will pafs through unequal Spaces in equal Times: fo that if you divide the Line BC into 100 equal Parts, during the firft of thefe Minutes, it will defcend 19 of thefe Parts, during the Second 17, during the Third 15, *&c.* and fo on, according to a Series of odd Numbers, down to an Unit; fo that the laft Part will go out in the laft of 10 Minutes.

The Reafon of which is founded on what is before fet down, *viz.* That the Velocities of Running Water are in a fubduplicate Ratio of their Heights; and confequently, that they are to each other as the Ordinates of a Parabola A B C, beginning at the greateft A B, and ending at the Point C; which caufes the Spaces paffed through in the fame Time, by the Surface of the Water A B, to be as the Series of odd Numbers, beginning at the greateft; which will be difcovered more plainly in the Tables that will by-and-by be prefented to View.

Agreeable to Experiments of this Kind, the fame *Torricelli* propofed (though he never finifhed it) a Problem, to find a Veffel of fuch a Figure, that being pierced at the Bottom with a fmall Hole, the Water fhould go out, its upper Surfaces defcending from equal Heights in equal Times. As fuppofe in the Conoidal Figure, *Fig.* 1. *Tab. feq.* BL is to BN as the fquared Square of L M is to the fquared Square of N O, and B N to B H as the fquared Square of N O to the fquared Square of H K, and fo on; the Water will defcend from A D C uniformly, till it comes to the Hole at B; for, let B P be the mean Proportional between B D and B H, fince the Square fquared of K H and of D C, are to each other as the Heights B H, B D; the Squares of H K, D C, will be in a fubduplicate Ratio of B H to B D, or as the Heights B P, B D; but the Velocity (and confequently the Quantity of Water) that goes out at B, by Reafon of the Preffure of B H, is in a fubduplicate Ratio of B D, B H, that is to fay, as B P to B D: therefore the Velocity of the Water defcending from H is to the Velocity of the Water defcending from D, as the Square of H K is to the Square of D C: But the circular Surface of the Water at H is to the circular Surface of the Water at D, as the Square H K to the Square of D C; therefore they will defcend and run out one as faft as the other: And if the Surfaces A D C run out in a Second, the Surface G H K will run out in a Second likewife, fince the Quantities are as the Velocities.

The fame Thing will happen to the other Surfaces at E and F, *&c.* but the Hole at B muft be fo regulated, that no confiderable

Acceleration may be made, and that the Water may not go out of the Hole irregularly, but in exact Proportion to its Weight. And, as *Marriotte* obſerves, that ſuch a Veſſel will or may ſerve for a Clepſydra or Water-Clock, an oblong Reſervoir of that Shape may be of excellent Uſe in the Driving of Mill-Wheels where Water is ſcarce, and the Opening is at the Bottom of it.

BUT to return from this ſhort Digreſſion, to which I have been inſenſibly carry'd, it is plain, from the foregoing Experiments, that the Supply of Water, which comes from one Place to another, is according to the different Sizes of the Spouts or Pipes of Conduct from which it proceeds, and according to the different Heights of the Head-Spring or Reſervoir from whence it falls; becauſe it is by the Difference of the Velocity or Force of Water, proceeding from Heights greater or leſſer, that the Quantity of Water proceeding therefrom is either greater or leſſer; for the exact Calculation of all which, the World is obliged to that curious and moſt exact Calculator of Fluids Monſieur *Marriotte*, in his late excellent Treatiſe, tranſlated by the Reverend Dr. *Deſaguliers*: But (as has been before noted) the *French* Meaſures differing pretty much from ours in *England*, it will be proper to ſay from the foregoing Tables, that the *French* Pint (ſomething near our Quart) is to our *Engliſh* Pint as 36 to 52; that the *Paris* Muid is to our *Engliſh* Hogſhead as 504 to 654; that the cubick Foot *French* is to our cubick Foot as 16 to 15, or rather, as their Squares 4096 are to 3375: That their Ounce, and conſequently their Pound, and other Weights, are to ours as 93 to 100. And, finally, that the Weight in Pounds of a cubical Foot *French*, is to the Weight in Pounds of a cubical Foot *Engliſh*, as 79 is to 65, or thereabouts. So that if a Column of Water of 12 Foot high, and half a Foot ſquare *French*, weighs 210 *l.* the ſame Number of Water in *Engliſh* Feet (being ſmaller than the *French*) will weigh but 172 *l.* $\frac{72}{79}$.

THE next Chapter illuſtrates the Practice of what goes before.

CHAP.

CHAP. XXXI.

A farther Calculation of the Coming-in of Water from Engines, or otherwise.

WE are now come to the real Calculation of the Motion of Fluids or Water in Pipes, which by the Rules *Marriotte* and others have laid down, will (through a Bore of three Lines, commonly call'd an Inch of Water) give 14 Pints in a Minute, and consequently, 3 *Paris* Muids about 2 Hgds. $\frac{3}{4}$ *English* in an Hour, and 56 *English* Hogsheads in 24 Hours, provided the Distance and the Friction occasion'd thereby be not too great, and that the Top of the Reservoir lie something above the Hole or Spout, out of which the Water proceeds; horizontal Jets giving more than those that spout upwards, and less than those which spout downwards; as Reason and Experience demonstrate.

AGREEABLE to this Rule of 12 Foot or 13 Foot high, above, the Hole of an Adjutage of 3 Lines will give an Inch of Water, that is 14 Pints *French*, about 20$\frac{2}{9}$ Pints *English* in a Minute, as above, as it spouts upwards, and when the Reservoirs have the same Height, but different Adjutages, the Expence of the Water will be in the same Proportion as the Holes of the Adjutages; *that is, as the Squares of the Diameters of the said Holes*. Thus, if a Reservoir of 13 Foot has an Adjutage of 6 Lines, and the Pipe of Conduct be, as it ought, 4 Times the same, that is, 2 Inches, it will give 4 Inches of Water: And if it is a Hole of one Inch Bore, the Pipe of Conduct being 4 Times as much, it will give 16 Inches in spouting upwards, provided the Pipe of Conduct which brings down be of a sufficient Bore all the Way, according to these Rules.

IN order to calculate the Expence of Water, take the Square of 3, which is 9, and if the Adjutage has a Diameter of five Lines, you must work thus by the *Rule of Three*; saying, If 9, the Square of 3, gives 14 Pints *French* in a Minute, how much will 25, the Square of 5, give? and the Answer will be 38$\frac{8}{9}$, being near 39; according to which the following Table is made.

A Table

A Table of the Expence of Water in a Minute through Spouts of different Bores, the Reſervoir 12 *Foot high.*

		Pints French.	Pints Engliſh.
Through an Adjutage of	1 Line Diameter	$1\frac{1}{2}$	$2\frac{1}{6}$
	2 Lines	$6\frac{1}{8}$	$9\frac{7}{9}$
	3 Lines	14	$20\frac{2}{9}$
	4 Lines	25	$36\frac{1}{9}$
	5 Lines	39	$56\frac{1}{6}$
	6 Lines	56	$80\frac{8}{9}$
	7 Lines	76	$109\frac{3}{4}$
	8 Lines	110	$158\frac{5}{9}$
	9 Lines	126	$184\frac{1}{4}$
	10 Lines	155	$223\frac{8}{9}$
	11 Lines	188	$271\frac{5}{9}$
	12 Lines, or 1 Inch,	224	$323\frac{5}{9}$

To return to Practice, according to the afore-mentioned Table, if a Pipe of an Inch Bore give 224 Pints *French*, or rather 323 Pints *Engliſh* in a Minute, how much will a Pipe of 2 Inches Bore give? State the Queſtion thus:

If 1, the Square of 1, give 323, what will 4, the Square of 2 give? Anſwer 1292 Pints *Engliſh*. See the Operation.

$$
\begin{array}{r}
1 — 323. \quad 4 \\
4 \\
\hline
1292 \\
\hline
\end{array}
$$

When the Heights of Water in Reſervoirs are different, the higheſt give more than the others in a ſubduplicate Ratio of their Heights, that is, as the leaſt Height is to the mean Proportional betwixt it and the greateſt Height.

According to this, if the Surface of the Water of the loweſt Reſervoir is 3 Foot high, and the Spout 3 Lines, you muſt take 6, which is the mean Proportional between 3 and 12; and becauſe 6 is to 3 as 14 is to 7, it may therefore be concluded, that a Re-ſervoir

ſervoir of 3 Foot high will give $\frac{1}{2}$ an Inch of Water, that is, 7 Pints *French*, or 10 Pints near $\frac{1}{4}$ *Engliſh*, through a Hole of 3 Lines; if the Height was of 4 Foot, you muſt take 48, the Product of 4 by 12, whoſe ſquare Root is near 7; then ſay, as 12 is to 7, ſo is 14 to a Number unknown, which by the Operation appears to be 8 $\frac{1}{6}$; and ſhews that ſuch a Jet will give 8 Pints $\frac{1}{6}$ *French*, about 11 Pints $\frac{1}{4}$ *Engliſh*, in a Minute; and on Calculations of this Kind the following Table depends.

	Foot		Pints French	Pints Engliſh
A Reſervoir of	6	high gave	10	$14\frac{3}{4}$ nearly.
	8		$11\frac{1}{2}$	$15\frac{1}{3}$
	9		$12\frac{1}{6}$	$17\frac{1}{4}$
	10		$12\frac{5}{8}$	$17\frac{3}{4}$
	12		14	$20\frac{2}{9}$
	15		$15\frac{1}{3}$	$21\frac{3}{5}$
	18		$17\frac{1}{6}$	$24\frac{3}{4}$
	20		$18\frac{1}{2}$	$26\frac{7}{9}$
	25		$20\frac{1}{6}$	$27\frac{4}{9}$
	30		$22\frac{1}{6}$	32
	35		24 *fere*	$34\frac{2}{3}$
	40		$25\frac{2}{3}$	$36\frac{1}{4}$
	45		$27\frac{1}{6}$	$39\frac{1}{4}$
	48		28, or 2 Inches	$40\frac{4}{9}$

N O W, to explain with the curious *Marriotte*, and his learned Tranſlator, what is meant by an Inch of Waret, as in the laſt Line, where there is ſet down 28 Pints, ot two Inches; it is ſufficient to obſerve, that it is an Unit, or Term, that *Marriotte* chooſes to expreſs himſelf by, as he has done before, when he ſays, that if a Spring gives 7 Pints *French*, onwards of 14 Pints *Engliſh*, in a Minute, it may be ſaid to give an Inch of Water: If it afford 14 Pints *French* in half, or 20 Pints *Engliſh* in a Minute, it may be ſaid to give two Inches, and ſo on.

B U T it muſt be noted, that when you make Tryal of any of the aforegoing Experiments, whether they are deſigned to demonſtrate *French* or *Engliſh* Meaſures, you muſt make the Hole 1 Inch

 and

and 1 Line, or 1 Inch $\frac{1}{12}$ Diameter, very nearly, the *French* Inch being pretty near as 13 to 12 is to ours *Engliſh*,

It having been proved then, by dividing 144 by 9, that a Bore of an Inch Diameter will (according to the Proportions before recited being 16 Times as large as a Bore of 3 Lines, coming from a Reſervoir 12 Foot high) produce 224 Pints *Paris* Meaſure, or about 324 of *Engliſh* Meaſure in a Minute; and that all other Heights in the aforegoing Table muſt conſequently follow the ſame Proportion, I have calculated the Table that follows, in which will be ſeen the Quantity of Water, *Engliſh* Meaſure, that any Reſervoir will give, from 48 to 6 Foot high, according to the different Sizes of Piping, from 1 Inch to 8 Diameter: The firſt Column is the Height of the Reſervoir, and the other ſeventeen the Diameters of the Pipes.

And from this and what goes before it is plain, that moſt Calculations relating to the Coming-in and Going-out of Water, may be ſolved; only it muſt be obſerved in all Diameters or Bores of Pipes, they muſt be made according to the *French* Inch, which is to ours, as the Square of 16, which is 256, is to the Square of 15, which is 225: Say we then, as 225 is to 226, ſo is 144 to a fourth Number required, which is 174, the Square whereof is very near 13 Lines $\frac{1}{2}$, or 1 Inch $\frac{1}{12}$ $\frac{1}{2}$ Line: And ſo much muſt the Diameter of the Inch Pipe be, to anſwer the following Table; if a 2 Inch Pipe, it muſt be 2 Inches 3 Lines; if a 3 Inch Pipe, 3 Inches 4 Lines $\frac{1}{2}$, and ſo on.

N. B. In what is ſet down in the following Table, proper Allowance is made for Friction, or rather the Interpoſition of the Air; but as the Valves before mentioned are now much in Uſe, that Friction or Interpoſition of Air, call it which you will, will be in a great meaſure taken off; and theſe Clacks, or rather Valves, may be uſed in Leaden, Wooden, or Iron Pipes, as well as Clay; ſo that the following Table, if it does err, yet is an Error on the right Side, and the Quantity of Water here ſet down, with the reſpective Heights to which it has been ſaid to riſe, will certainly be enough.

A Table

A Table ſhewing what Quantity of Water, Engliſh *Meaſure, any Reſervoir will diſcharge, from 48 to 6 Foot high according to the different Sizes of Piping from* 1 *Inch to* 8 *Diameter, in a Minute.*

Height of the Reſerv	In. 1 0	Inch. 1 ½	Inch. 2	Inch. 2 ½	Inch. 3	Inch. 3 ½	Inch. 4	Inch. 4 ½	Inch. 5	Inch. 5 ½	Inch. 6	Inch. 7	Inch. 8	Inch. 9	Inch. 10	Inch. 11	Inch. 12
60	240	280	960	1440	2160	2880	3840	4800	6000	7200	8640	11760	15360	19441	24000	29040	34960
80	245	490	980	1470	2205	2940	3870	5900	6025	7350	8820	12005	16780	19845	24500	29646	36380
90	276	556	1104	1656	2484	2912	4416	5520	6900	8280	9936	13524	17664	22356	27600	32396	39744
10 0	284	568	1136	1704	2556	3408	4544	5680	7100	8420	10224	13916	18176	22704	28400	34364	40896
12 0	324	648	1296	1944	2916	3888	5184	6480	8100	9720	11664	15776	20736	26244	32400	39204	46659
15 0	345	680	1380	2070	3105	4140	5520	6900	8125	10350	12420	16905	22080	27945	34500	41754	49680
18 0	396	796	1584	2376	3564	4652	6336	7920	8900	11880	14256	18404	25344	32076	39600	47916	55924
20 0	429	858	1716	2574	3861	5148	6741	8580	10725	12870	15444	21021	27456	34749	42900	51909	61776
25 0	439	878	1746	2634	3951	5268	7024	8780	10975	13170	15804	21511	28096	35549	43900	53119	63216
30 0	512	1024	2048	3072	4508	6144	8192	10240	12800	15360	18432	25088	32768	41472	51200	61952	73728
35 0	556	1112	2224	3336	4994	6672	8896	11120	13900	16680	20016	27234	35584	44936	55600	66308	80064
40 0	580	1160	2378	3480	5220	6960	9280	11600	14500	17400	20880	28420	36120	46980	58000	70180	83520
45 0	628	1256	2512	3768	5752	7536	10048	12560	15700	18840	22608	30772	40192	50864	62800	75978	90432
48 0	647	1294	2588	3862	5933	7764	10352	12940	16165	19410	23292	31703	41208	52407	64700	76287	93168

Note, The Numbers above recited are Pints *Engliſh* Meaſure ; to reduce which into Hogſheads, &c. you muſt divide by the Number of Pints in a Hogſhead ; all which will be found in the Tables which are calculated for that Purpoſe.

So that the Ufes of the foregoing Table being very plain, I need not enlarge on it. If you would know how much Water a 4 Inch Pipe will yield in an Hour, that comes from a Refervoir 30 Foot high, look in the Table againft 30, and under the 4, and you will find 8192 Pints in a Minute; that multiplied by 60, gives 491520, and divided by 512, the Pints in an Ale Hogfhead, and the Anfwer is 970 Hogfheads.

AGAIN, in like Manner, if you would know how many Hogfheads in an Hour a Pipe of 2 Inches Bore, will produce from the fame Height, there will be anfwering 2048, which, multiplied by 6c, produces near 231 in an Hour; but if it was for a lefs Height, as fuppofe 6 Foot, it would give but 112 Hogfheads in an Hour; and all this, when the Refervoir is under 150 or 200 Yards, at moft, of the Place; for if it be a long Length, and there be Turnings or Windings, and up-hill and down in it, it would caufe a great Friction, and would not yield above 50 or 60 Hogfheads, at moft, in an Hour, as Experience does fufficiently evince, for if the Allowance for Friction be as 9 to 4, as the learned Annotator on *Marriotte* fays it is, then a Pipe of 2 Inches Diameter, and that goes above 1000 Yards; as fuppofe 12, 13, or 1400, then fuch a Pipe would give but 49 Hogfheads $\frac{7}{9}$.

AND thus much for the Coming-in and Going-out of Water in Pipes from Refervoirs of different Heights, where there is little or no Friction; but, 'tis much to be feared, that Water that is raifed by Engines will not produce fuch great Quantities, nor fcarce fo much as Refervoirs at a great Diftance, allowing for Friction; fince 'tis plain, from the Principles of all thofe who have wrote of *Staticks, That a Force, which forces up a Body perpendicularly, grows lefs equally*: Becaufe the Gravity of the Body, which is thrown up conftantly, pufhes it downwards again; and fo its Motion upwards muft continually decreafe, and be wholly deftroy'd, when the Impetus upwards, which is receiv'd from that impulfive Power that throws it up, becomes equal to that Impetus which its own Gravity gives it downwards, that is, that Bodies thrown upwards muft be retarded, and ceafe to rife, as foon as the two Impulfes are become equal, and then immediately begin to defcend again; becaufe then the Impulfe of Gravity is greater than that of the Projection; fince Gravity leffens the Velocity of the Impulfe upwards, and by its contrary Action deftroyes the Motion upwards, with the fame Force that it would produce a Motion downwards, which is uniformly, according to the Laws of Motion accelerated, the Force which pufhes upwards muft alfo decreafe uniformly.

formly.

formly. And ſince the Deſcent of Water coming from different Heights is found to increaſe, by the foregoing Tables and Accounts, in a ſubduplicate Ratio of its Height, its Riſe, and alſo Quantity, muſt conſequently decreaſe in the ſame Proportion.

THUS, to invert the Terms, if an Engine throw up 647 Pints of Water 6 Foot high, through a Pipe of an Inch Diameter, the ſame Engine will not be able to throw up above 240 Pints to a Height of 48 Foot, through a Pipe of like Diameter. But as the moſt exact Rules that can be given in Theory, will, in all Probability, fall ſhort, and, perhaps, wide of the Truth, when reduced to Practice, I have with ſome Difficulty procured (from ſome of the moſt eminent Places in *England*, where Engines are made,) Account of the Bore of their Pipes, the Diſtance the Water is carry'd, and the Height to which it riſes; becauſe, farther than yet mentioned, the impulſive Force of an Engine (notwithſtanding Engineers now put two, three, or four Regulators to it) is alternate, or in ſome other Degree intermiſſive; which is the Occaſion that Engines will by no Means yield the ſame Quantity of Water, as Reſervoirs or Springs (whoſe Motion is regular and uniform) will. And this Account will, in a great Meaſure, explain the Effect of every particular Kind of Engines, and how preferable they are, in many Circumſtances, to one another.

CHAP. XXXII.

Of Friction, *its Etymology, and the Effect it has on Pipes of* Conduct, &c.

FRICTIO, a Subſtantive of *Frico*, has its Derivation, as ſome will have it, from the *Greek* of *Frigeo*, or rather (as *Schrevelius* notes it) of *frigo*, *torreo*, *torrefacio*, to heat, make warm, burn, and the like; from whence, ſays that laborious Author, comes φρυγμός ἡ ὁ *torrefactio*, *frixio vel frictio*; and *Coles* in his little Dictonary will have it from the *Greek* Τρίβω, or from the *Hebrew Pur*, which tranſlated into the *Latin* Language ſignifies *diſrumpi*, *i. e.* to break, rub, chafe, or fret; in all which Senſes it may well be taken, as it imports that Letting, Hindrance, or Stoppage in Fluids, and in all Mechanick and Hydraulick Motion, occaſion'd by that Rubbing that is inſeparable from the Laws of Motion in Engines, *&c.*

IT

It is a Word that ſeems not ſo well underſtood, at leaſt not heretofore uſed in the Senſe it now is, as whoever will give himſelf the Trouble to inſpect *Scapula*, and other ancient *Lexicons* and *Gloſſaries*, will find; tho' there we find, that *Celſus*, *Lib.* 1. makes uſe of it, in a Caſe not much unparallel to the Senſe we now do, when ſpeaking of a Journey he had taken, ſays, *in ipſo quoque itinere frequens* Frictio *erat*: But the learned *Merſennius*, *Gallilæo*, and others have uſed it in a much larger Senſe, in their Applications of it to Mechanical and Hydroſtatical Calculations; and *Wallis* is found (tho' he has not defin'd the Word, as he has done many others in theſe Arts) in many Places of his Treatiſe on the Axis in *Peritrochio*, to uſe the Word with great Freedom, however limited the ſame was in antient Authors: Let me ſet it done in his own Words, *Cap.* 7. *Prop.* 3. *Quæ hinc oritur frictio, impedit quo minus orbiculus, circa axem ſuum expedite volvatur*; and again, a little lower, *& quidem eo magis, quo axis major eſt propter majorem, propterea frictionem.* And, to conclude, a little farther he ſays, *Et propterea ob frictionem ſæpius repetendam difficilius movebitur roto minor.*

And from theſe Intimations it appears to be, that the learned *Harris*, in his *Lexicon Technicum*, *Vol.* I. *ſub titulo* F. ſays of it, that it is a Word often uſed by Writers on Mechanicks, for the Reſiſtance which ariſes to the Motion of any Engine from the Matter (and I may add the Shape and Size of the Wheels, *&c.*) rubbing againſt one another, and againſt any other Body; and of this Reſiſtance, ariſing from Friction, he tells us, there was a large Diſcourſe printed in the *Memoirs* of the *Royal Academy* of Sciences at *Paris* for the Year 1699, by Monſ. *Amonton*, wherein that ingenious Author makes ſeveral Experiments, which give Rules for to find out and calculate Tables of this Reſiſtance ariſing from Friction, and of that which is the Reſult of all that Rubbing, Chafing, and Stoppage of Cords uſed in Pulleys, the Subſtance of which ſhall be, if this Book can be procured, exhibited in its proper Place. Returning now to the Friction that is in Pipes, wherein it muſt be obſerved, that later Writers on Hydroſtaticks have uſed this Word in a more extenſive Manner, than what is to be found in *Gallilæo*, *Wallis*, and others, who have treated of Motion; I mean the celebrated *Marriotte*, who by ſome curious Obſervations has found, that Water in Pipes is conſiderably ſtopp'd by the Friction that is againſt the Sides of them, occaſion'd, as ſome will have it, by the Viſcuoſity and Cohæſion of the Particles of Water one to another, which being, as it were hook'd together, impede and hinder each other in their Paſſage, eſpecially in great

great Lengths, of which whoever reads *Part* V. *Diſcourſe* 1. concerning Pipes of Conduct in *Marriotte*'s elaborate Treatiſe of Hydroſtaticks, may be more particularly inform'd.

Now, as from hence it chiefly comes to paſs, that Water that paſſes a great Way, and from a Spring-Head, as it were naturally, never riſes well to its own Level, how much ſoever may (to the Diſadvantage of young Hydroſtaticians have been ſaid to the contrary, it will not be improper, in the Courſe of this Chapter, to conſider ſomething of the Method for the Determination of this Friction, or the Reſiſtance that is in the Paſſage of Water through long Tracts of Land, and in narrow Tubes, the Velocity of which is ſtopp'd by this Friction; for the Diſcovery of which, take the following Experiment, as we have it from *Marriotte* aforeſaid.

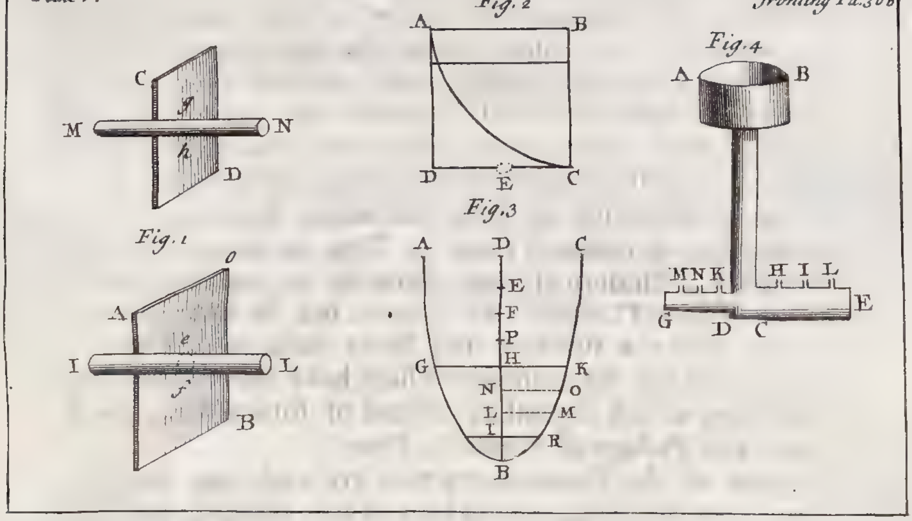
Let A B C D (*Fig.* 1. *Tab. ſeq.*) be a Pipe of 6 Inches Diameter, and 6 Foot high; the Pipe C E is 3 Inches Diameter, and the Pipe F G 1 Inch: Three Holes were made at the Points H I L, that at H was 2 Lines wide, that at I 4 Lines, and the laſt at L was 8 Lines wide: In the other Branch F G, the Holes K N M were diſpoſed after the ſame Manner, in reſpect of their Nearneſs to the Tube A B C D. The Pipe A D being full, the Operator let the Water ſpout ſucceſſively through the three Holes H I L, the other ſtill continuing ſhut: the Jet at L roſe the higheſt, being the wideſt; but a narrow cauſes a conſiderable Friction that retards the Velocity of the Water, and hinders it from running faſt enough to ſupply the Adjutage. But in the Holes H and K, as the Velocity thro' the Pipe is 16 Times leſs than when the Water goes through L and M, the Friction in the narrower Pipe is inconſiderable, and does not ſenſibly retard the Jet K more than the Jet H, and they both riſe pretty near to the ſame Height. It follows likewiſe, that if you diminiſh the two Holes I and N, for Example, each of them a Line, then the Jet through F will not riſe ſo high as it did, and that through N will riſe higher; becauſe there will be leſs Friction in the Pipe F G, that overcomes the Defect from the Air's Reſiſtance; and in the Pipe C E, this Diminution of Friction will not be conſiderable, but the Reſiſtance of the Air will be a little greater, than in that of 4 Lines; and this it is that has deceiv'd a great many Perſons, that have made their Experiments in narrow Pipes, as F G, and they have, with the greateſt Part of the Fountain-Makers, concluded, that Water roſe higher through narrow Adjutages, than through wide ones, which is contrary to Reaſon and Experience, provided the Pipe of Conduct be not too narrow, that is, to ſupply them.

THE ſame Thing happens when the Adjutages are 6 or 7 Inches long, or even 2 or 3 Foot, the Jet will be higher through a plain Hole in a Plate, not above a Line, or a Line and a half thick, the Experiment will (according to *Marriotte*) be eaſily made: If you have a Pipe of 6 or 7 Inches Diameter, as A B C D, *Fig.* 2. and in the Pipe E F of a ſufficient Bore, 2 equal Holes be made at G and H, the firſt having the Adjutage G I, and the other only the Thickneſs of the Metal; for you will ſee the Jet through H will go much higher than through G I; and the more you diminiſh the Height of I G, the nearer will its Jet riſe to that of H; whence it follows, that the long Adjutages that are put to the Mouths of Dolphins in Fountains are very defective.

AND tho' the Adjutages ſhould be a little conical, the Jet will ſtill be retarded; concerning which take the following Experiment: A Glaſs Pipe, a Foot in Height, and an Inch Diameter, having a Hole of two Lines and a half, ſpouted only ten Inches and a half high, when there was a little Cone in it; but when it was made without a Cone, it ſpouted eleven Inches and a half; which ought to be a good Direction to thoſe that make Adjutages or Spouts to Fountains, not to contract them at Top, as many do, but to make them exactly cylinderical; nor likewiſe to contract the Termination of the Pipes of Conduct all at once, but by Degrees, and in ſuch a Manner, that the Friction may be as little as poſſible; ſince 'tis his, that by all the Experiments which have been made, that cauſes that Friction, which depreſſes, inſtead of forwarding, the Riſing of the Jets, and Paſſage of Water in Pipes.

To trace all the Experiments that are and may be made to demonſtrate this Friction, would be a Work of itſelf, and entirely beyond the Room I can allow in this Treatiſe; becauſe a Multitude of Examples would rather puzzle, than inſtruct any Learner in the Practice of Hydroſtaticks and Hydraulicks, for which this Deſign is chiefly calculated; nor indeed can the Experiments that are made in ſmall Caſes have their full Weight in larger, it being found, (as has been already hinted in the Preface) that *Marriotte* does not allow enough for the Decreaſe of the Velocity of Water through a long Pipe of Conduct; all which having been ſo amply laid down in the Preface, I need not repeat it here again; but that this Friction is nearly in Proportion to the Length that it runs, rather than to the Friction that is againſt the Side of the Pipes; nor is it indeed an eaſy Matter to diſtinguiſh from which of the Cauſes it is, that this Velocity of Water is ſtopp'd, whether from Friction or the Cohæſion of watery Particles one to another, or from the Reſiſtance that is in Air, which

Plate V. fronting Pa. 368



poſſeſſes itſelf of all Vacuities, and, till it is expell'd by the greater Force of Water, muſt occaſion a conſiderable Reſiſtance thereto, as the Noiſe and Roaring of Water in Pipes do ſufficiently demonſtrate.

THERE is alſo another Reaſon, why it is not ſo eaſy to determine the *Rationale* of Friction by the before-mentioned Experiments, and which is, That a little Thread of Water finds more Reſiſtance (eſpecially in open Air) at its firſt coming out, than great Jets do; as ſmall Bullets or Shot, tho' ſhot out of the ſame Piece, will not reach ſo far as large ones. And there is yet another, which proceeds from the different Impulſe or Force of Water from Engines or Reſervoirs of different Heights. All which Circumſtances, I ſay, produce different Effects, as the Cauſes are different. But be this Decreaſe of the Velocity of Water from what Cauſe it will, the Table that will be by-and-by inſerted, corroborated, and explain'd, as it will be from real Facts in larger Caſes, will be as near the Truth as can be.

IT will be ſufficient, in Addition to what has been ſaid on this Head, to add, that the Reſiſtance of Air, and the other Cauſes before-mentioned, is ſuch, that Water (how duly and regularly ſoever plac'd, and how well ſoever adjuſted the Pipes of Conduct and their A[illegible]ages are) will not riſe by about $\frac{1}{8}$ or $\frac{1}{9}$ in open Air, nor by [illegible] in encloſed Pipes (where the Diſtances are great) ſo high as the original Reſervoir or Baſin.

Of the Proportion of Conduct-Pipes.

FROM thoſe curious Obſervations that Monſieur *Marriotte* has made at *Chantilly*, and other Places, and from large Adjutages and Pipes of Conduct, it appears, and may be taken for a fundamental Rule, that a Reſervatory of 52 Foot high ought to have a Conduct-Pipe of 3 Inches Diameter, when the Adjutage is 6 Lines, and that the Jet will then riſe to the greateſt Height that it ought to have.

TO compare the Breadth of this Conduct-Pipe with that which Reſervatories ought to have, and the Breadth of Adjutages, the following is a proper Rule, ſuppoſing that the Velocity of the running Water be equal in both Pipes, and that there be no more Friction in one than the other: But if the Number of Inches be quadruple, the Section of the Bore of the Conduct muſt be four Times greater that the Velocity of the Pipes may be equal.

HERE follows the Rule as it is eſtabliſhed by Mr. *Marriotte*;

As the Number of Inches which one Jet gives, is to the Number of Inches which another Jet gives; ſo is the Square of the Diameter of the Conduct-Pipe of the firſt, to the Square of the Diameter of the Conduct-Pipe of the other.

Example:

If you would know what Diameter you muſt give your Conduct-Pipe to have a Jet 100 Foot, through an Adjutage of 12 Lines, you muſt take a Height of 52 Foot, as above, for your Standard, which through an Adjutage of 6 Lines, having the Pipe 3 Inches Diameter, gives 8 Inches; and that becauſe, by the Table of the Heights of Jets, the Reſervatory of a Jet of 100 Foot ought to be 133 $\frac{1}{3}$; you ſay then, As 52 is to 133, ſo 64, the Square of 8, is to 170; and the Square Root of 170 being pretty near 31, you ſee, that a Reſervatory of 133 Foot, through 6 Lines, will give 13 Inches, and through an Adjutage of 12 Lines, 52 Inches of Water. Then, as 8 is to 52, ſo is 9, the Square of 3, (which the Diameter of the Pipe ought to be,) to 58, whoſe ſquare Root is 7, and near $\frac{2}{3}$, which will be the Diameter of the Pipe that was ſought; but, for greater Security, you may, ſays our oft-quoted Author, give it 8 Inches.

To ſum up all that has been ſaid, and to adjuſt the Friction we have been ſo long diſcourſing of in this Chapter, the general Rule is, that Water brought a conſiderable Diſtance, loſes $\frac{1}{8}$ of its Velocity; or, in other Words, that it will not riſe ſo high as the Spring-Head is by $\frac{1}{8}$; ſo that if the Deſcent from a Spring-Head to a Reſervoir or Building be 128 Foot, you are, according to this general Rule, by which many Plumbers and others are governed, to divide it by 8, and the Produce will be 16, which ſhews that the Water will not riſe ſo high as the Spring-Head by 16 Foot; and that, conſequently, inſtead of the Water's riſing to 128 Foot high, it will only riſe to 112 Foot, 16 Foot being allow'd for Friction, or the Interpoſition of Air, &c.

'Tis true, where the Fall of Water is ſo great, as it is in the aforegoing Example, there will be little Occaſion to reaſon ſo minutely concerning the Friction that is to be allow'd: But where the Fall is not above 8 or 10 Foot, and at a great Diſtance, 'tis there that an exact Calculation is very neceſſary, leſt the Owner be diſappointed in his Labour and Expectation.

According to ſome of the Rules before-mentioned, the natural Current or Fall for Water muſt be at leaſt two Foot in a Mile; and

and the Diſtance here being ſuppos'd to be 526 Yards running, the Queſtion is, how many Inches will be requiſite for ſuch a Current or Dependance.

See the Operation.

If 1760 require 24 Inches, what will 526 Yards require?

$$\begin{array}{rrl} & 24 & \\ \hline & 2104 & \\ & 1152 & \\ \hline 1760) & 13624 & (7\tfrac{1304}{1760}\ \text{Inches.} \\ & 1304 & \\ \hline \end{array}$$

And the Anſwer is 7 Inches and near $\frac{2}{3}$. Then again, to determine the Friction, ſuppoſe that the natural Fall be 12 Foot in this Length of 526 Yards, divide the 12 by 8, and the Produce is 1 Foot 6 Inches, which, added to the 2 Foot natural Fall, makes 2 Foot 1 Inch and $\frac{2}{3}$; ſo that 12 Foot is much more than ſufficient, and, if you will, you may carry your Spring, and conſequently your Reſervoir, higher: And, in the firſt Caſe, were the Fall no more than 3, 4, or 5 Foot, ſuch Water would paſs.

But as this Allowance of $\frac{1}{8}$ of the Height of the Spring-Head is in general Terms, and according to the Rules the Plumbers have eſtabliſh'd amongſt themſelves, is ſuppos'd to be ſufficient and exact, yet by the curious Experiments of *Marriotte* and others, a more certain Rule for Friction may be eſtabliſh'd.

That ingenious Author produces it as a certain Rule, That the Difference of the Heights of Jets, or he might have ſaid, in other Words, the Deſcent of Water from the Original or Spring-Head to the Reſervoir, or Place aſſign'd for its Uſe, *is in a ſubduplicate Ratio of its Height:* And tho' it is certain, that this Gentleman has made uſe of it, to demonſtrate the Riſe of Jets of Water in open Air, which has doubtleſs as great, or, perhaps, a much greater Effect, than any Friction in incloſed Pipes; yet by this it is, that we may come as near the Matter of Fact as poſſible, and be more certain as to our Calculations on this Head.

To come then to Example, (*vid. Pag.* 270. of Dr. *Deſaguiliers*'s Tranſlation,) and which he ſeems to eſtabliſh as a general Rule, up to or nearly equal to the Height of the Spring-Head, he allows, that a Reſervoir (which, by the By, ought to be at leaſt 10 or 15 Foot ſquare) that is 5 Foot 1 Inch high, will raiſe the Water 5

Foot, and ſo on, in a ſubduplicate Ratio to their reſpective Heights; and conſequently, that, as to this, it is but one Inch abated of what it would riſe to by Nature; and purſuant to this it is, that the following Table is calculated, which is from Rules which farther ſhew, that if a Spring of 5 Foot 1 Inch in Height abates only 1 Inch, the ſame Spring, being 10 Foot 4 Inches, will abate 4 Inches; and the higher you go, the greater will the Diſproportion be.

The TABLE.

The Height of the Spring-Head.		The Height the Water will riſe to.	
Foot.	Inches.	Foot.	
5	1	5	0
10	4	10	0
15	9	15	0
21	4	20	0
27	1	25	0
33	0	30	0
39	1	35	0
45	4	40	0
51	9	45	0
58	4	50	0
65	1	55	0
72	0	60	0
79	1	65	0
86	4	70	0
93	9	75	0
101	4	80	0
109	1	85	0
117	0	90	0
125	1	95	0
133	4	100	0

And this is, I think, ſufficient as to the Friction allow'd for the Deſcent of Water in cloſe Pipes, and a Demonſtration, that an Allowance of $\frac{1}{8}$ can be no certain Rule for it. What remains to be obſerved on this Head will naturally fall in, when we come to treat of *Jets d'Eau*.

CHAP.

CHAP. XXXIII.

Of the ſeveral Rules in Arithmetick with which a Learner in Hydroſtaticks *ought to be informed.*

IT is of great Import, in order to the better underſtanding and calculating of Water-Works, that the Learner make himſelf Maſter and be well acquainted with the ſeveral Rules of Arithmetick following.

I ſhall paſs by *Numeration*, *Addition*, and the like, becauſe it is ſuppoſed that few are unacquainted with thoſe Rules; tho' there are others, ſuch as the *Rule of Three*, the *Rule of Falſe*, *Square Root*, *&c.* very neceſſary to be known by all Hydroſtaticians, which they may be at a Loſs to comprehend, tho' well ſkilled in many other Arts and Sciences, it being for the ſake of ſuch, that this Treatiſe is chiefly deſigned.

THE *Rule of Three* is the moſt uſeful of any that belongs to *Hydroſtaticks*, it being from two Numbers known that a Third which is unknown is diſcovered, which we ſhall many Times have Occaſion to mention, in the Courſe of this Treatiſe.

SUPPOSE then, according to a general Rule, laid down in the Expence or Coming-in of Water, that a Pipe or Spout of three Lines Bore give 14 Pints *French* of Water in a Minute, what will a Pipe or Spout of 7 Lines give?

See the Example:

SAY, as 9, the Square of 3, is to 14, ſo is 49, the Square of 7, to a 4th Number unknown.

$$
\begin{array}{rrr}
9 & 14 & 49 \\
 & & 14 \\
\hline
 & & 196 \\
 & & 49 \\
\hline
 & 9) & 686 \; (76\tfrac{2}{9} \\
 & & 63 \\
\hline
 & & 56 \\
 & & 54 \\
\hline
 & & 2 \\
\hline
\end{array}
$$

And the Anſwer is 76 Pints $\frac{2}{9}$ of a Pint.

Of the Rule of Falſe.

THE *Rule of Falſe* is another Rule that is of ſome Uſe in Hydroſtatical Calculations.

THERE is a Ciſtern with three unequal Cocks, containing 60 Gallons of Water; and if the greateſt Cock be emptied in an Hour, if the ſecond be opened, it will be emptied in three Hours, *&c.* Now it is demanded, in what Time the Ciſtern will be emptied, if all the Cocks run together.

NOW, as the Solution of all Queſtions in the *Rule of Falſe* are perform'd from a ſuppoſed fictitious Number, to find out a real one, let the Calculator ſuppoſe, that the Ciſtern will empty itſelf in half an Hour's Time, or 30 Minutes; then there muſt empty at the greateſt Cock 30 Gallons, or one half; at the ſecond Cock 15 Gallons, or one Quarter; and at the leaſt 10 Gallons, or one Sixth; which added together makes 55: But this is too little by 5.

SAY then, by the *Rule of Three*, if 55 Gallons be expended in 30 Minutes, what Time will 60 Gallons take to run out, or be expended in?

See the Example:

As 55 is to 30, ſo is 60 to a 4th Number ſought for.

$$\begin{array}{r} 30 \\ \hline 55)\ 1800\ (32\tfrac{40}{55} \\ 165 \\ \hline 150 \\ 110 \\ \hline 40 \\ \hline \end{array}$$

So that the Anſwer is 32 Minutes, and ſomething more than 40 Seconds.

I Shall only ſet down one Example more, from the *Double Rule of Falſe*, with which I ſhall conclude what I have to obſerve on theſe two Rules, and the *Rule of Three*, from which all theſe Examples are deduced.

A Veſſel holds 60 Gallons, and has 4 Cocks to it; and being fill'd with Water, or any other Liquor, if they be all ſet open at once, the Liquor will run out in 24 Hours Time: Now the 2d Cock will empty as much as the firſt, during the ſame Time; and the 3d will empty three Times as much as the 1ſt in the ſame Time; and the 4th will empty five Times as much as the firſt: The Queſtion is, what Number of Gallons each Cock will empty?

The firſt Thing to be done is to add all the four Numbers together, thus:

1ſt Cock	1	Quantity.
2d Cock	1	equal.
3d Cock	4	Times as much.
4th Cock	5	Times as much.
In all	11	

Say

SAY then, if 11, the Quantities of Water in the Whole, require 60 Gallons, what will 1 require?

$$\begin{array}{l} 11 \quad 60 \quad 1 \\ \quad\quad\ \ 1 \\ \hline 11)\ 60\ (5\tfrac{5}{11} \\ \quad\quad 55 \\ \hline \quad\quad\ \ 5 \\ \hline \end{array}$$

the Quantity the firſt Cock empties, which Quantity alſo the ſecond Cock empties.

Again; If 11 requires 60, what will 4 require?

$$\begin{array}{l} \quad\quad\quad\ 4 \\ \hline 11)\ 240\ (21\tfrac{9}{11} \\ \quad\quad 22 \\ \hline \quad\quad 20 \\ \quad\quad 11 \\ \hline \quad\quad\ \ 9 \\ \hline \end{array}$$

the Quantity the 3d Cock muſt empty.

But the Integer being once found, the whole Sum may be eaſier found out in the following Manner; the firſt Quantity being $5\frac{5}{11}$, the Caſe will ſtand thus;

	Gallons.
1ſt Cock will empty	$5\frac{5}{11}$
2d Cock the ſame	$5\frac{5}{11}$
3d Cock 4 Times the Quantity	$21\frac{9}{11}$
4th Cock 5 Times as much	$27\frac{3}{11}$
The Fractions added together make 22, which is 2 Times the Denominator 11, and ſo the Addition will ſtand thus:	60 0 the Anſwer required.

N. B. THE Queſtions before-going will be of conſiderable Uſe, when we come to treat particularly of the Coming-in of Water, and the Expence or Going-out of the ſame; and altho' the ſame might be done quicker by the Rules of Algebra, yet as that is a Science underſtood by few, I have choſen to uſe this plain Method of Arithmetick.

Of

Of the Square Root, and its Uſes in Hydroſtaticks.

THE Square Root is likewiſe a Rule that ought to be well unſtood by Hydroſtaticians.

Here follows a Table of the Simple Roots, with their Squares.

Roots.	1	2	3	4	5	6	7	8	9
Squares.	1	4	9	16	25	36	49	64	81

FOR Example, let 576 be a ſquare Number required, of which you are to find the Root: You muſt begin on the right Hand, and make a Point at every ſecond Figure, and then it will ſtand thus:

$5\dot{7}6$, the Point being made over the 7.

THE firſt Thing I do is to find the neareſt Square to 5, which by the Table is 4.

Subſtract then $\underline{\;4\;}$ from 576,
And there remains 176 and the Quotient is 24.

LOOK again into the Table, and find the neareſt Square to the Root 17, and you will find it to be 4, which I place in the Quotient, which makes 24, and 16 remains.

AFTER this, you are to examine if the laſt 4 multiply'd by itſelf, will make out the Number 16 which remains, which you will find it will exactly do; and 576 proves to be an exact ſquare Number, of which 24 is the Root.

AGAIN, ſuppoſe you were to find out the Square Root of any other Number, let it be of 119025.

YOU muſt firſt make Points either above or below every other Figure, beginning on the left Hand thus, 119025; or which is better, divide them into three Claſſes, and then the Figures ſtand thus: 11 | 90 | 25

$$\begin{array}{c|c|l} 2 & & \\ 11 & 90 & 25\ (3 \\ 9 & & \end{array}$$

The 2d Operation then is to find the nearest Square of 11, which is 9, and that 9 deducted, the Sum stand thus: for the two next Divisions.

```
  9
290|25
```

The third Operation is in this Form:

```
   | 3  |                 11 90 35 (34
 2 | 54 | 25- (34            9
11 | 90 |                 ----
 9 | 64 |               6) 290
```

In the fourth Operation, the whole Quotient 34, being doubled, makes 68, and will be a new Divisor, to be put under the left Hand Figure 2, after this Manner:

```
                          119025 (34
                             9
                          -----
   | 3  |               64) 290
 2 | 54 |                   256
11 | 90 | 25-(34           -----
 9 | 64 | 8                  34
```

The left Hand Figure 6 of this Divisor, since it can be had in 34 five Times, this new Quotient 5 is joined to the former behind the crooked, and is also set down under 5 in the vacant Place of the Classis; so that the Operation stands thus:

```
                          11 90 35 (345
   | 3  |                    9
 2 | 54 |                 -------
11 | 90 | 25            64) 290
 9 | 64 | 85 (345           256
   | 6 4|                 -------
                       685) 03425
                             3425
```

Of

CHAP. XXXIV.

Of ſeveral Weights and Meaſures neceſſary to be known for the better explaining the Diviſion, Diſtribution, and Expence of Water.

FOR the better Calculation of the Quantity of Water coming from Engines and Springs, and the Expence thereof, in Fountains, Caſcades, and the like, it will be neceſſary to ſet down the following Account with the Addition of ſuch Tables of Weights and Meaſures, as are ſtatutable and cuſtomary in *England*, and which moſt neceſſarily belong to this practical Treatiſe; which, when compar'd with thoſe of *France*, the Learner may, with the more Certainty, compare and adjuſt thoſe which *Marriotte* and others have made Uſe of in their Hydroſtatical Calculations.

THAT ingenious Gentleman and his Reverend Tranſlator tell us, that with them in *France* a cubick Foot of Water weighs 70 Pounds *French*, (i. e. $65\frac{1}{2}$ *Engliſh*) and contains 35 Pints *Paris* Meaſure; but by this it is plain, neither their Weights nor Meaſures are the ſame with ours; for it has been proved, by undoubted Experiments, that a cubick Foot of Water *Engliſh* weighs 76 Pounds *Troy* Weight, but of *Averdupois* but 62 *lib.* $\frac{588}{1000}$: And in this Account they tell us, that 70 *lib.* contains 36 Pints *Paris* Meaſure, when filled up to the Brim, (which muſt be near equal to ſo many Quarts *Engliſh*;) but if the Water (ſay they) riſes above the Brims of the Veſſel before it runs over, the *French* Pint (about our *Engliſh* Quart) will weigh (as before) 2 Pounds, and 35 ſuch Pints only, will be contained in a cubick Foot. Now here, in like Manner, it is apparent, that they differ from us; for if half a Pint *French* weighs 1 Pound, as their Authors intimate, if it be compar'd with our *Troy* Weight, it is too little, if with our *Averdupois*, too much. It being found from the ſame careful Experiments, as before mentioned, that a cubick Foot of Water *Averdupois* is 62 *lib.* 9 *oz.* $\frac{414}{1000}$, or 76 Pound *Troy*. But I ſhall chuſe to make uſe of *Averdupois* Weight in all my Calculations, rather than *Troy*; for tho' moſt Liquids that are ſold are weigh'd by *Troy* Weight, yet as the *Averdupois* is the moſt general Weight now made uſe of, and as its

Tables are the moſt agreeable to my preſent Purpoſe, when I ſay Pounds, or any other Number or Quantity of Weight, I mean that of *Averdupois*; and when I make uſe of any Quantity of liquid Meaſures, I mean that of Ale.

But if any one is ſo curious as to have his Account in *Troy* Weight, it is proper he ſhould know from the ingenious and very careful Experiments of Dr. *Wybeard* and others, that 14 Pound *Averdupois* is equal to 17 *Troy*: To reduce the one to the other, ſay then, by the *Rule of Three*,

If 14 Pound *Averdupois* be equal to 17 Pouud *Troy*, how equal is 125 Pound to any Number unknown? Anſwer $151\frac{11}{14}$.

See the Example.

$$
\begin{array}{r}
14 : 17 :: 125 \\
17 \\
\hline
875 \\
125 \\
14)\ 2125\ (151\frac{11}{14} \\
72 \\
\hline
25 \\
\hline
11 \\
\hline
\end{array}
$$

By which it appears that 125 *l. Averdupois* is equal to 151 *lib.* $\frac{11}{14}$ of *Troy*.

To proceed with the ingenious *Marriotte* and his Tranſlator, we are by them inform'd, that a *Paris* Muid or Barrel contains 280 *French*, (about 280 Quarts of *England*) or 288, if the Water is fill'd up to the Brim, (which it ought to be.) Now this likewiſe ſeems diſagreeable to our *Engliſh* Meaſures; nor is our *Engliſh* Hogſhead (as will appear by and by) equal to the Muid, which I beg Leave to explain, becauſe of the Difficulty and Uncertainty that may be in the Way, when we come to calculate and compare *Jets d'Eau*, and the Expence of Water from Engines, or otherwiſe, I mean thoſe of *England* with thoſe of *France*.

To reconcile thoſe two Meaſures together with the more Exactneſs, it is to be noted from Sir *Jonas Moore*, and others of good Note, in their Compariſons of Foreign Meaſures with the *Engliſh*, that the *French* Ounce is to ours (and which ſhall be the Standard

from

from whence we make all our Calculations and Tables,) as 93 is to 100, by which it will in its proper Place appear, that the *Paris* Muid is not equal to our *Engliſh* Hogſhead.

Now to find the true Proportion between *French* and *Engliſh* Meaſures, if 14 Pints *French* (28 *Engliſh*) contains 26 Pounds, and in 14 Pints *Engliſh* there are contain'd 17 *lib.* $\frac{1}{2}$ *Averdupois*, and ſomething more, (which it appears to do,) then the Difference between thoſe two Meaſures, by doubling the 17, and 26 in order to avoid Fractions, is as about 36 to 52.

If therefore a circular Hole of Water of an Inch Diameter give 14 *French* Pints in a Minute, how many *Engliſh* Pints will it give in the ſame Time; and becauſe it will give more *Engliſh* than *French*, ſtate it thus:

$$
\begin{array}{rrl}
36 : 52 :: & 28 & \\
 & 52 & \\
\hline
 & 56 & \\
 & 140 & \\
\hline
 & & \text{Anſwer.} \\
36) & 1456 & (40\tfrac{16}{36} \text{ near } \tfrac{1}{2}. \\
\hline
 & 16 & \\
\hline
\end{array}
$$

And ſo many Pints *Engliſh* will a circular Hole of an Inch Diameter give, at the ſame Time that it gives 28 Pints *French*, (or about 28 Quarts *Engliſh*) Let 36 : 52 be then the Proportion.

Again, if a Pint *French* of Water (about a Quart *Engliſh*) weighs 1 *lib.* $\frac{3}{4}$ *Engliſh*, then 288 Pints of the ſame Meaſure will make 504 Pounds *Engliſh*, and ſo many Pounds *Engliſh* a *Paris* Muid holds, and conſequently the Proportion between the *Engliſh* Ale Hogſhead and the *Paris* Muid is as 654 to 504, 654 Pounds *Engliſh* being the Contents of *Engliſh* Pounds in a Hogſhead, as 504 *Engliſh* Pounds are in a *French* Muid: If therefore an Inch of Water, or in other Words, a circular Hole of an Inch Diameter, give 72 *Paris* Muids or Barrels in 24 Hours, how many *Engliſh* Hogſheads will it give? Anſwer, 55 Hogſheads, and about 30 Gallons.

Let the Case be thus stated.

$$
\begin{array}{r l}
654 : 504 :: 72 & \\
72 & \\
\hline
1008 & \\
3528 & \\
\hline
 & \text{Hogsh.} \\
654)36288 & (55\tfrac{318}{654} \text{ about 30 Gallons.} \\
3588 & \\
\hline
318 & \\
\hline
\end{array}
$$

In like Manner may we (with the Observations made by *Wallis* and others) find out the Proportion that our *English* cubick Foot has to the *French*. The same learned Author, in *Prop.* XI. *Cap.* 14. *Pag.* 728. of his *Mechanical Essay*, saying, that upon a careful Examination, he had found the *Paris* Foot to exceed ours, as $14\frac{1}{2}$ is to $13\frac{1}{2}$ (or rather as 29 to 27, the Mercury in the Barometer rising but 27 Inches *French* to 29 *English*,) he might as well have said, as 14 is to 13, or 15 to 14; or as the ingenious Translator of *Marriotte* has it, as 16 is to 15; so that the cubical Content of the *French* Foot is to that of *England* as 4096 is to 3375; which is also what Monsieur *Marriotte*, in his practical Rules for *Jets d'Eau*, *pag.* 263. sets down, where he tells us, that a cubick Foot *Paris* Measure of Water weighs 70 Pound *French* or 65 $\frac{1}{10}$ *English*, then in a Foot solid *English* there are *62 lib. 9 oz.* so that the Proportion between the *French* Foot and the *English* is near as 62 to 65, or nearer, as the Square of 15, which is 3372, (not 3528, as is by Mistake in *Marriotte*) is to 4096, the Square of 16.

To come to Example:

IN 256 cubick Feet *French*, how many cubick Feet *Engliſh*?

SAY, as 3375 (French) is to 4096 (English), ſo is 256 to the Content requir'd.

```
                   4096
                    256
                  -----
                  24576
                 20480
                 8192
                -------
3375)  1048576 (310 2326/3375.
          3607
           2326
          -----
```

HAVING thus adjuſted the Method of comparing of ſome of the *French* and *Engliſh* Meaſures together, it will be neceſſary to take a View of thoſe that are purely *Engliſh*, and from thence draw out ſuch Tables, as may complete the reſt, ſo as to be of Uſe to the preſent Purpoſe, with their reſpective Weights, cubical Contents, *&c.* Nor let it be thought that theſe are needleſs Speculations, ſince it will be demonſtrable enough in the Courſe of this Treatiſe, that the Weights and cubical Contents of all Fluids in all its various Circumſtances, eſpecially Water, is one of the moſt uſeful Parts of Knowledge, that belongs to practical Hydroſtacy, and without which indeed all the Theory of it would be uſeleſs and inſignificant.

THIS being premiſed, it will be requiſite, in the next Place, to proceed to the Work itſelf, I mean that of *Engliſh* Weights and Meaſures.

ALL Meaſures of Capacity, (ſays the ingenious Mr. *Ward*, in his excellent Treatiſe of Arithmetick,) both liquid and dry, were at firſt made from *Troy* Weight, (*Vid.* the Statute of 9 *Hen.* III. 51 *Hen.* III. and 12 *Hen.* VII. *&c.*) where it was enacted, that eight Pounds *Troy* Weight of Wheat, gather'd out of the Middle of the Ear, ſhould make one Gallon, and that there ſhould be but one Meaſure for Wine, Ale, and Corn throughout this Realm, (as *Vid.* the Statute of 17 *Edw.* III. and 15 *Ric.* II.) but Time and Cuſtom, ſays this ingenious Author, has alter'd Meaſures as well as Weights, and perhaps for the ſame Reaſon; there being now three different Meaſures, one for Wine, one for Ale and Beer, and another for Corn.

The common Wine Gallon, by which Wine and Brandy, and other Liquors, are meaſur'd and ſold, are ſuppos'd to contain 231 Cubick Inches, and ſhould hold of pure Rain, or running Water eight Pound one Ounce and eleven Drams, as the very ingenious and curious Sir *Jonas Moore*, and others, have obſerv'd, and that is in *Averdupois* Weight, and nine Pound one Ounce one Dram in *Troy* Weight; therefore to get a true Wine-Gallon, make a ſquare Veſſel, that ſhall have all the Squares and Depths ſix Inches thirteen hundred Parts of an Inch; or if you weigh with *Averdupois* Weight, eight Pound one Ounce eleven Drams of pure running or Rain Water: Either of theſe, ſays this great Obſerver of Meaſures, will find out a true Gallon Wine-Meaſure.

But Dr. *Wybeard*, in his Treatiſe of Tectometry, Page 289. does ſuppoſe the Wine-Gallon to contain but 224 Inches, or 225 at moſt; and, purſuant to this, Mr. *Ward* tells us, that two very eminent Surveyors in the *Exciſe* made a very careful Experiment in a particular Veſſel made for that Purpoſe before Mr. *Flamſtead* and Mr. *Halley*, which confirm'd what Dr. *Wybeard* had ſet down before.

In and about *London* there are Diſtinctions of Beer and Ale, though not very widely different from each other; but in all other Parts of *England* the following Tables of Beer or Ale, whether ſtrong or ſmall, are to be obſerv'd, by a Statute of Exciſe made *Anno* 1689. with this Difference, that the Firkin of Beer contains nine Gallons, and conſequently the Kilderkin eighteen Gallons; the Barrel thirty ſix, and the Hogſhead ſeventy two; but in the Meaſure which I have choſe rather to make uſe of, to wit, Ale, the Firkin is but eight Gallons, the Kilderkin ſixteen, the Barrel thirty two, and the common Hogſhead ſixty four Gallons.

The Gallon for Ale and Beer holds two hundred and eighty two Inches ſolid, and weighs of pure Water ten Pounds, three Ounces, $\frac{426}{1003}$, about ſeven Drams; therefore a ſquare Veſſel made to prove the Truth of this Gallon ought to be ſix Inches, and $\frac{55}{00}$ Parts of an Inch each Way, and the Weight ten Pound, three Ounces, forty Parts, *Averdupois*, as before.

Here

Here follows a Table of fuch Meafures, with the Weights and Cubical Contents of each Veffel, as near as it is poffible fuch Calculations fhould be made, being Averdupois Weight.

The TABLE.

Cub. Inch.	℔	℥	ʒ		*Pint.*	*Gall.*		*Firk.*	*Kild.*	*Bar.*	*Hogf.*
35½	1	4	7	1							
282	10	3	8	8	1						
2256	81	12	0	64	32	1	0				
4512	163	4	0	128	64	16	2	1			
9024	327	0	0	256	128	32	4	2	1		
18048	654	0	0	512	256	64	8	4	2	1	

The Ufe of this Table is fo obvious, that I need not enlarge upon it, but fhall only obferve, that 18048 Cubick Inches are contain'd in one Hogfhead, and that the fame weighs 454 Pound. Now the Cubick Inches being reduc'd into Feet, produce fomething more than 10½ Cubick Feet; and the 454 Pound reduc'd into hundred Weights, produce four hundred and fix Pound, and fo many hundred Weight are in a Hogfhead *Englifh*.

Before I quit this Chapter, it is proper to fet down from the curious Experiments of Dr. *Wybeard*, and others, that one Ounce of pure Running or Rain Water Troy will fill 1.8949 Inch, and one Ounce Averdupois 1.72556 Inch; one Pound Troy will fill 22.7368 folid Inches, and one Pound Averdupois, 27.609 folid Inches. One Foot folid will hold 76 Pound Troy, and fixty two Pound 500, as before, Averdupois.

Here follows a Table for the converting folid Inches into Weight of Water Averdupois. The Table N° I. turns folid Inches of Water into Ounces Averdupois, and the Table N° II. turns Ounces Averdupois of Water into folid Inches, and are the Calculations of that excellent Mathematician Sir *Jonas Moore* before mentioned.

N° I.

	Ounces Aver.
1	0. 59522
2	1. 159044
3	1. 738566
4	2. 313088
5	2. 897611
6	3. 477133
7	4. 056655
8	4. 636177
9	5. 215699

N° II.

	Inches and Parts.
1	1. 72555
2	3. 45112
3	5. 17668
4	6. 90224
5	8. 62780
6	10. 35356
7	12. 07892
8	13. 80448
9	15. 53004

EXAMPLE: In an Ale-Gallon, 282 ſolid Inches, how many Ounces Averdupois.

ANSWER, 163. 426 Ounces, or 16 Pound, 3. 426 Ounces.

By the Table N° I.

200--	115.904406
80--	46.361776
2--	1.159044
In all	163.426

So in 500 Ounces of Water there is 862 ſolid Inches by Table N° II. and in a Foot ſolid, there will be anſwering 1728 Inches, 62 Pound, 9. 414 Ounces.

THE neareſt Proportion in Troy Weight, that 36 ſolid Inches will hold, is 19 Ounces Troy of Water, and one Pound Troy of Water will fill, as before recited, 22.7368 Inches, and one Pound Averdupois 27.609 Inches.

HENCE is found a very good Way to meaſure any irregular Body, that by no mechanical Art can otherwiſe be done: Fill any Veſſel brim full of Water, and then dipping in your Body, receive carefully all the Water that runs over, and weigh it, and by the laſt two Tables, turn that Weight into ſolid Inches; otherwiſe, if your Veſſel be regular that holds the Water, obſerving the Riſing of the Water, and find the ſolid Feet or Inches anſwering.

BUT

But more to our preſent Purpoſe, in Hydroſtaticks, or rather Hydraulicks, let it be required to know the Cylindrical Weight of Water that an Engine muſt drive, the Length of whoſe Pipe is 1500 Yards, and the Pipe itſelf four Inches Diameter.

To find the Content of this Pipe at the End, ſay as 14 is to 11, ſo is 16, the Square of four, to the Content requir'd.

EXAMPLE.

$$\begin{array}{r l}
14 : 11 :: & 16 \\
 & \underline{11} \\
 & 16 \\
 & \underline{16} \quad \text{Inch.} \\
14) & 176 \; (12 \tfrac{8}{14}, \text{ or } \tfrac{4}{7} \\
 & \underline{36} \\
 & \underline{8}
\end{array}$$

And the Anſwer is twelve Inches, and a little more than half a one, and ſo much is in an Inch in Length; but as there are 36 Inches long in a Yard, I multiply that by 12 and a half in the following Manner,

$$\begin{array}{r}
36 \\
\underline{12\tfrac{1}{2}} \\
432 \\
\underline{18} \\
\underline{450}
\end{array}$$

And the Anſwer is 450 Inches in a Yard. Now by the Table;

Inch.	Ounces.
400--	231.3088
50--	28.9761
	260.6849

In all 260 Ounces, 6849, or 16 Pound 6 $\frac{12}{100}$ Ounces, or thereabouts; but that we reject as unneceſſary.

SAY we then, If one Yard Cylindrical of Water, in a Pipe of four Inches Diameter, weighs 16 Pound 4 Ounces, how much will 1500 Yards weigh? Anſwer, 24375 Pound, or 217 C. 71 ℔. Weight, beſides the Friction, Reſiſtance, &c.

BUT becauſe the calculating the Cubick and Cylindrical Weight of Water for Square Spouts, and circular Jets or Pipes, may be difficult and tedious to the Learner; I have, (to finiſh this Chapter) ſubjoin'd a Table of ſuch Meaſures: And as it has been before obſerv'd, that the *French* Ounce (conſequently all other of their Weights) are to the *Engliſh*, as 93 is to 100, ſo alſo it is obſervable, that as to Meaſures, the Cubick Foot *French* is to the *Engliſh*, as the Square of 16, which is 4096, is to the Square of 15, which is 3375; and that conſequently they are, in Reſpect to each other, as 79 to 65 Thoſe who are skill'd in Algebra would do it quicker; but to demonſtrate this the better and plainer,

LET it in the firſt Place be requir'd to know, That if a Foot Cubick of Water *French* weigh 69 Pound 12 Ounces, (as by *Ozanam*'s Tables it appears to do,) how many Pound *Engliſh* does it weigh, ſuppoſe the *Engliſh* Foot were of equal Dimenſion with the *French*? Anſwer 79 Pound, &c.

EXAMPLE.

```
93 : 100 :: 69 : 12
              16
            ----
             474
             69
              12
            ----
            1176
             100
          -------- 16
   93) 117600 (1264 (79
       ----    ----
        246     144
       ----    ----
        600      0
       ----    ----
         420
        ----
          58
        ----
```

Rejecting the Fraction, the Anſwer is 79 Pound. But as the *Engliſh* Foot is leſs than the *French*, and conſequently cotnains a leſſer

leffer Number of Pounds in Proportion thereto, even as 4096 is to 3375, fay we again,

As 4096 is to 3375, fo is 79 to a fourth Number.

See the Operation:

$$
\begin{array}{r}
4096 : 3375 :: 79 \\
79 \\
\hline
30384 \\
23632 \\
\hline
4096)\ 266724\ (65\ \frac{464}{4096} \\
20944 \\
\hline
464 \\
\hline
\end{array}
$$

By which it appears, that the Weight in Pounds of a Cubical Foot *French*, is to the Weight in Pounds of a Cubical Foot *Englifh*, as 79 is to 65, or thereabouts; and the fame holds good in Cylindrical Meafure.

To come to Example then: Suppofe, with *Marriotte*, *Difc.* III. *Rule* v. *Page* 135. of the Tranflation, that a Column of Water of twelve Foot high, and half a Foot Square *French*, weighs 210 Pounds *French*, how many Pounds *Englifh* will twelve Foot of the fame Water weigh? Now fince the *Englifh* contains a lefs Number of Inches than the *French* does, fay,

As 79 is to 65, fo is 210 to a fourth Number unknown.

$$
\begin{array}{r}
65 \\
\hline
1050 \\
1260 \\
\hline
\text{Anfwer.} \\
79)\ 13650\ (172\ \frac{72}{79} \\
\hline
575 \\
\hline
72 \\
\hline
\end{array}
$$

And purfuant to this Proportion, here follows two Tables of the Cubical and Cylindrical Weight of Water, from one Inch to a Foot

Foot ſquare or circular, taken at every Yard in Length, from which may at one View be ſeen what the cubical Contents, Weight, and Quantity of Water is, that drives all ſorts of Mill-Wheel; and alſo what the Cylindrical Weight of Water is that a Mill-Wheel muſt drive at any determinate Length or Number of Yards.

A Table of the Cubical Contents and Weight of any ſquare Jet, Spout, or Pipe, Engliſh *Meaſure; as alſo the Cylindrical Weight of the ſame taken at every Yard in Length.*

Cub. in Inches Square.	Averdupois Weight.		Dit. in Pounds.			Cylin. in Inches Square.	Averdupois Weight.		Dit. in Pounds.		
Inch.	Ounces.	Parts.	Lib.	Oz.	Parts.	Inch.	Ounces.	Parts	Lib.	Oz.	Parts.
1	20	86279	1	4	86, &c.	1	16	34933	1	0	34, &c.
1½	41	72558	2	9	72, &c.	1½	32	49867	2	0	49, &c.
2	83	55116	5	3	55, &c.	2	62	50440	3	12	50, &c.
2½	125	17674	7	13	17, &c.	2½	98	35313	6	2	35, &c.
3	187	76511	11	11	76, &c.	3	147	52658	9	3	52, &c.
3½	250	35340	15	10	35, &c.	3½	196	37764	12	4	37, &c.
4	333	70464	20	13	70, &c.	4	262	19621	16	6	19, &c.
4½	417	25580	26	1	25, &c.	4½	[illegible]	[illegible]4541	20	7	84, &c.
5	521	56975	31	9	56, &c.	5	409	80400	25	9	80, &c.
5½	625	88370	39	1	88, &c.	5½	491	76571	34	7	76, &c.
6	749	06064	46	13	06, &c.	6	588	54782	36	13	54, &c.
6½	876	23718	54	12	23, &c.	6½	688	47207	43	0	47, &c.
7	1024	17671	64	0	17, &c.	7	804	71027	50	4	71, &c.
7½	1168	30594	73	0	30, &c.	7½	917	95481	57	5	95, &c.
8	1335	21356	83	7	21, &c.	8	1049	10029	65	9	10, &c.
8½	1502	12088	93	14	12, &c.	8½	1180	23312	73	12	23, &c.
9	1689	88529	105	9	88, &c.	9	1327	76756	82	15	76, &c.
9½	1877	65110	116	1	65, &c.	9½	1475	11570	92	3	11, &c.
10	2086	27900	130	6	27, &c.	10	1634	21921	102	2	21, &c.
10½	2294	90690	143	6	90, &c.	10½	1803	13685	113	15	13, &c.
11	2524	39759	157	12	39, &c.	11	1912	02667	119	8	02, &c.
11½	2753	88828	172	1	88, &c.	11½	2163	29793	135	3	29, &c.
12	3004	24176	187	12	24, &c.	12	2317	61852	144	13	61, &c.

The Uſe of this Table is ſo plain, that I need not enlarge much upon it; for ſuppoſing you have 760 Yards of Square, or in this Place we will rather ſay, Circular Pipe of ſeven Inches and a half Diameter, it is plain that a Yard in Length of Water within ſuch a Pipe

Pipe weighs fifty-seven Pounds, five Ounces, ninety-five Parts: This may be multiplied by 760; but because those odd Measures and Fractions will create much Trouble, I have chose rather to multiply the 917 Ounces, 95481 Parts, by 750 as is shewn in the Example.

```
       Ounces Parts
        917 95481
              760
       -----------
      5507728860
     642568367
    -------------  Pounds  Parts
16) 69764565560 (43602 | 85347  Something more than
     57                               half a Pound.
     --
      96
      --
       045
       ---
         136
         ---
          85
          --
           55
           --
            76
            --
             120
             ---
               8
               -
```

CHAP. XXXV.

Of artificial Fountains, Jets d'Eau, &c.

AGREEABLE to what has been before treated of, those who have wrote of the Theory and Conduct of Water for Reservoirs, Fountains, *&c.* have endeavoured to explain themselves in about twenty Propositions; which, like so many Maxims, serve for the Foundation of all that can be said on the Rising or Spouting of Water in Fountains; and they are chiefly these.

PROP.

Prop. I. *That Air may be compreffed, but not Water.*

Prop. II. *That Water cannot enter into a Veffel, but there muft come forth as much Air, except the Water be fent in by Force.*

Prop. III. *From whence it follows, by the contrary Reafon, (as* de Caus *has it,) that if a Veffel be full of Water, it cannot be emptied, fo as that the Air fhall not enter therein.*

Prop. IV. *That there can be no Vacuum, or Space, entirely devoid of Matter (though there may be a difpers'd Vacuum) in the World.*

Prop. V. *If Air be preffed into a Veffel wherein there is Water, and that you give it Paffage by fome Pipe, the faid Water fhall come forth with Violence.*

Prop. VI. *That Water weighs upon that which fuftaineth it according to its Height.*

Prop. VII. *That Water naturally afcends to the Level of the Place from whence it did defcend.*

By thefe and fome other Propofitions it is, that the Rife of Water in Syphons, Syringes, Fountains, &c. are demonftrated, which I fhall not here confider feparately, but take a fhort View of Air, which by its Gravity, Elafticity, and Impulfe, agitates Water and other Fluids; referring my Reader for his fuller Directions in this Matter to thofe Chapters where the Gravity, Elafticity, and Impulfe of Air, are more fully handled.

Let A B C D Fig. I. Tab. feq. be a Veffel filled to the Brim with Water, and in it let there be placed a Curve Tube, or Syphon, E G H K, likewife full of Water, the Orifice whereof I K is for that Purpofe ftopp'd with the Finger or otherwife. If now you remove your Finger from I K, every Body knows experimentally, that the Water will run out from I K to Z, rifing up in the mean Time in that Part of the Syphon E G which is fhorteft, and coming down in the longeft H K, as long as the Water in the Veffel continues higher than the Mouth of the fhorteft Leg E F.

Now to know the Force and Manner whereby this Operation is brought about, ftop the Syphon again with your Finger at I K, by

by which Means the Water in that, and in the Veſſel will ſtagnate. Suppoſe then X to be the upper Place of the Air, which preſſes here upon the Water, and produces the horizontal Plane of the Water, A D, throws P Q to R S whereof L M, N O, P Q, and R S, are equal Parts; and thereupon, according to the preceding Rules, the Part L M will be preſſed with the Weight of Air gravitating thereupon.

Suppose the Preſſure L M, to be a hundred Pounds, the Water Column P Q I K by *b*, of ten Pounds; and that of the Air R S T V, being of the ſame Height, by *c*, of one Pound: Now ſince L M, N O, P Q, which are equal Parts of the ſame horizontal Plane A Q, and all Water; and to all which we may ſuppoſe, that a Line or Thread may be drawn without paſſing through a ſolid Body, or any other Fluid beſides Water; and ſince by the Action of the Syphon, the Plane L M moves, or is preſſed downwards, that of N O upwards, and that of P Q again downwards; if every Thing be reduced to reſt by ſtopping the Orifice I K, the Powers whereby the ſaid Planes were preſſed upward and downwards will be equal, and L M being preſſed downwards, by the Weight of the Air Column L W M, that is by *a*, or a hundred Pound, N O will be preſſed upwards and P Q downwards by the ſame.

If we now join to the Weight of this Air Column of *a*, or one hundred Pounds, which preſſes P Q downwards, the Water Column P Q I K of *b*, or ten Pounds, by which I K is likewiſe preſſed downwards, the Force or Weight which preſſes I K, will conſiſt of *a* join'd to *b*, or of one hundred Pounds, and ten Pounds, to wit, of the Air and Water Columns together. And ſo, it is with this Force that the Water gravitates downwards to Z. If now the horizontal Plane paſſing through I K be extended to V, and T V ſuppos'd equal to I K, then will T V be preſs'd downwards by the whole Column of Air I V X, that is, by R S X of *a*, or one hundred Pounds, (the ſame being equal to L M V,) and by R S T V of *c*, or one Pound, that is, of *a* and *c*, or one hundred Pounds, and one Pound join'd together. Now juſt ſo much Force is the Part I K, or rather the Air preſſing againſt I K, or the Finger, (if we don't conſider the Thickneſs thereof preſs'd upwards,) ſo that here is ſeen two Powers preſſing againſt each other on I K, or the Separation of Air and Water operating and acting againſt each other; and the Fact is obvious toany one.

Marriotte, *Part* IV. *Diſc.* 1. of his *Hydroſtaticks*, tells us, that the like Effects will follow from Weights put upon a Syringe. For Example, Let A B C D, *Fig.* 2. *Tab. ſeq.* be a Syringe of three Inches diameter, having at its Paſſage a Bore of four Lines at E, the Piſton is F G, which has a Plate below its Handle, to which it is fix'd, that the Syringe may be kept upright, the Piſton being juſt within; there is Water pour'd in, to fill from the Height of the Piſton L, as far as E; M N, O P, are two Sticks fix'd to the Body of the Syringe, on which hang two equal Weights Q and R, with two Cords on each Side of the Syringe. I ſay, that if theſe two Weights, which we may ſuppoſe to be Air, weigh twenty Pounds, any Jet will ſpout through E, as high as by any of the receiv'd Laws of Hydroſtaticks it would, (if it were ſo much incumbent Air,) and would produce the ſame Effects, though it were in *Vacuo*. What any additional Weight would effect, or how much higher they would raiſe the Water in larger Tubes, is fully prov'd by *Marriotte* in *Fig.* 83, 84, 85. of the aforeſaid Diſcourſes, to which I refer my Reader.

THE Obſervations made on this Head by the aforeſaid very curious Author, have produc'd a Machine, which he calls *Fons Heronis*, or *Hero's Fountain*, deſcrib'd in his Treatiſe *De Spiritalibus*, according to the Tranſlation of *Commandinus*, which take as follows.

LET E F G H (*Fig.* 3. *Tab. ſeq.*) be a Machine full of Water, as far as the Line I L, a little below E F; and a Pipe M N, which is well ſolder'd at M and O to the two Plates E F, G H, which make the Top and Bottom of the Trunk, to hinder the Air from going into it. The Trunk E G will ſerve for a Ciſtern or Reſervoir.

IT is neceſſary, however, that there ſhould be another Trunk equal to the firſt, as C D I K, full of Air, to which the Pipe M N may be ſolder'd. When we pour the Water through M, it will go down through N, as far as K I; and being riſen up as far as P Q, the Air contain'd in the Space Q P C D, and in the Pipe X Y, open at X, and well ſolder'd to the two Trunks, will not be able to go out through A, and will be condens'd by Degrees, till there be made an Æquilibrium between the Weight of Water in M N, and the Spring of the included Air.

FOR

For Example: If the Water be raiſed to R S, the Air contain'd in the Space C D S R in the Pipe X Y, and in the Space E I F L, will be condens'd by the Weight of the Water M S, and will preſs the Water I H G L; then if we open the Adjutage A, whoſe Pipe deſcends near H G towards V, the Water will ſpout to the Height A Z, very near equal to the Height M S, becauſe the Air which is preſs'd by the Height of the Water M S makes the ſame Effort upon the Water I G, as if the Pipe M S, (full of Water,) was above the Water I L; and the Water which ſhall fall from the Jet, paſſing through M will re-enter into the lower Trunk; and by this Means the Jet will laſt till all the Water, (which reach'd from the Extremity V, of the Pipe A V, to the Extremity Y of the Pipe X Y) be gone out in ſpouting.

If in this Place we ſhould conſider Water, not only as to its Riſe, but the Beauty it is to afford in Fountains, certain it is, that the Beauty of it conſiſts in that Uniformity and Tranſparency which it affords at the going out of the Adjutage, of which there are ſeveral kinds, as being ſubject to the leaſt Friction of any yet contriv'd; but of this more in its proper Place.

According to what has been before ſet down, Water will not riſe higher, if ſo high, as the Fountain which ſupplies it; but however, there are Methods whereby Water in artificial Fountains may be made to riſe higher than the Water in the Reſervoirs or Ciſterns which ſupply them, without any Means whatſoever, ſave the Gravity and Weight of Water itſelf.

Let A B C D, *Fig.* 4. *Tab. ſeq.* be an open Ciſtern, from which an open Tube N R is carried downwards, through the Covering E H of another Ciſtern E F G H, ſhut ſo cloſe, that no Air can get in, paſſing down to R, almoſt to the Bottom of the Ciſtern F G.

From the upper Part of this loweſt Ciſtern E H, there ariſes a ſecond Tube S T, paſſing on almoſt as high as T D, or the Lid of a ſecond Ciſtern D C K I, which is likewiſe cloſed; and from thence there is again deriv'd a third Tube to L M Q, which is ſtopp'd with a Cock, which has a large Orifice at M O. Moreover, in the Ciſtern D C K I there is a Hole at P, which can be open'd and ſhut by another Cock or Stopper.

 To

To ſet this Machine to work, pour in Water at the Orifice P into the Ciſtern D C K I, till the Tube L Z Q O be full; ſhut the the Cock M O, continuing to pour Water in at P, till the Water riſes in the ſaid Ciſtern to the Height T Y, or level with the Mouth of the Tube T; then ſhut the Cock P, and pour in Water to the Ciſtern till it riſes to the Height 2 T. This is not indeed abſolutely neceſſary here, but is preſcrib'd, to the End that by taking the Height of the ſame Water in both the upper Ciſterns, the Calculation may be the more ſimple, and conſequently the more intelligible to unexperienc'd Perſons.

This being done, and every Thing at Reſt, upon the Opening M O you will ſee the Stream of Water riſing up to V, through the middle Orifice of the Plate 5, 6. or at leaſt to a conſiderable Height above the uppermoſt Superficies 2 T of the Water which is in the Ciſtern A B C D and D C K I, and which preſſes upon the Stream 6 V. And in this Place it muſt be obſerv'd, that forasmuch as the Water of the upper Ciſtern A B C D deſcends into the lower E F G H during the Play of the Fountain, there muſt be a Hole in the latter, from whence the Water may be diſcharg'd; which being done, it muſt be ſtopp'd up again, if you play the Fountain in the Manner you did before; or otherwiſe you may place a little Pump at 2 through the Tube N R, down to the Bottom F G, and then pump the Water out of the lower Ciſtern E F G H through N, the Cock being open'd in the Ciſtern D C K I.

We have already given an Account of the Fountain of *Hero Alexandrinus*, as deſcrib'd by *Marriotte* with ſome Improvement. But whereas, in that of *Hero* it is not poſſible to make that which ſpouts out to attain to a Height equal to that of the Fall; but in this, notwithſtanding the Height of the Machine was no more than three Foot and a half, the Jet roſe five Foot higher than the Water in the upper Ciſtern.

Let G A F H *Fig.* 5. *Tab. ſeq.* be the uppermoſt Ciſtern, lying open, and having under it two ſmaller, and every where Air-tight Ciſterns A B C D and D C E F; each of thoſe has an Orifice or Hole, one at M, and the other at N, and both of them may be render'd alſo Air-tight, by ſtopping them with a Cock, cover'd with a wet Bladder, or a Cock. There are likewiſe two cloſe Ciſterns below S T R P and P R Q O. From the Bottom A F of the uppermoſt Ciſtern G A F H, there paſſes a Tube K I downwards

wards almoſt to the Bottom R T of the Ciſtern P R S T, but in ſuch a Manner, that the ſame, or whatever it contains, has no Communication with the Ciſtern D C E F, through which it paſſes. And from 3 in P S, there is carried a Tube 3 L upwards, juſt below the uppermoſt Plane D F of the Ciſtern D C E F; from the Bottom of which C E there deſcends again at 9 a Tube at 9 *b*, terminating in the other Ciſtern Q O P R, very near the Bottom of it Q R; and this ſame Ciſtern Q O P R ſends again a Tube 4 Z upwards, which beginning at 4, is carried on to Z, exactly under the uppermoſt Plane A D of the Ciſtern A B C D. Laſtly, at A D there is a Tube *p r*, cloſe ſolder'd at 5, 6, which riſes to *r b* only, or a very little higher than the Plane A D, and paſſes downwards to P, or nearer to the Bottom B C.

On the Top of this laſt Tube another was fix'd *r* 8, which at W 8 was cover'd with a flat Plate, having a ſmall round Hole in the Middle of it, through which the Stream was to paſs, which was cloſed at the Joint R with the fineſt Plaiſter, ſo that it was impervious either to Water or Air.

Now to work this Machine it is to be turn'd upſide down, ſo that the Ciſtern G A F H be undermoſt, and having fill'd both the Ciſterns A B C D and D C E F with Water at the Orifices M and N, the ſaid Orifices are to be ſtopp'd with a Cork and Bladder, putting a Finger in the mean Time upon the Hole in the little Plate W 8, to the End that the Water pour'd in at M, or ſo much of it as was above *p*, might not run out.

It will not be neceſſary to give an Account here, how the Water ſubſiding or ſinking from G A F H, through the Tube K I preſſes the Air out of the Ciſtern P R S T through the Tub 3 L upwards, which finding no Room any where but by preſſing downwards, the Water in the Ciſtern D C E F, protrudes the ſaid Water towards the Ciſtern O Q R P, with much greater Force than that of its own or ſingle Gravity. At which Place the Water likewiſe aſcending, the Air is protruded with the ſame Force from O Q R P, through 4 Z to the Ciſtern A B C D, which cauſes the Water to ſpring out of the Tube *p* 8 after this Manner, with almoſt the Force of both the Weights of the Water Columns Y H and K I; and in this Manner may be deduc'd the Operations of the aforegoing Fountains, Syphons, &c. without any Calculation. Nor will it be difficult to any one that underſtands this aright, to cauſe a Stream of Water to riſe up to any given Height by a requiſite

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Multiplication of Ciſterns and Tubes, the Height of the Deſcent of Water being likewiſe given, as may be ſeen in *Bockler*'s elaborate Treatiſe of *Architecture* and *Hydroſtaticks*, which I have much Occaſion to conſult in this and the following Volumes.

But to finiſh this Account: The Machine we have been juſt giving an Account of, may be improv'd in ſuch a Manner, as not to have Occaſion to invert it, nor yet ſtop the little Hole of the Column W 8, with the Finger, or any Thing elſe, by Stop Cocks in other proper Places, and by making the Orifices M N, above at A F, as is known to every Body that has any Skill in theſe and other kinds of Water-Works.

Fig. 6. *Tab. ſeq.* is a Scheme wherein the Motion of Water in a Curve Tube is deſcrib'd, of which more in its proper Place.

And *Fig.* 7. *Tab. ſeq.* is the compleat compound Fountain of *Hero*'s, as deſcrib'd by *Graveſande*, the Conſtruction of which is very plain and obvious.

CHAP. XXXVI.

Of the Conſtruction and Uſe of a Gauge for Meaſuring of Water, and of the Diſtribution and Expence of it to Cities, Towns, Gardens, &c.

Amongst the Works of the celebrated *La Bion*, I find a Gauge, which he appears to have taken from *Marriotte*, for to know the Quantity of Water which a Source furniſhes, which is of a Rectangular Parallelopepidon of Braſs well ſolder'd, about a Foot long, eight Inches broad, and as many in Height, more or leſs, according to the Quantity of Water to be meaſured, having ſeveral round Holes very exactly drill'd in it, at an Inch in Diameter; and others for half an Inch of Water to paſs through; and alſo others for a Quarter of an Inch of Water to paſs through them: All which ought to be drill'd, ſo as that their Centers may be of the ſame Height. The upper Extreams of the Inch-Holes muſt be within two Lines of the Top of the Gauge; and the Holes are ſtopped

stopped with little Brass square Plates, adjusted in the Grooves, 1, 2, and 3. There is Brass Partition crossing the Vessel mark'd 4. fix'd about an Inch above from the Bottom, and drill'd with several Holes to make the Water pass more freely. This Partition is made to receive the Shock of the Water falling from the Source into the Gauge, and hindering it from making of Waves; so that it may the more naturally run out through the Holes; where note, that to give a cylinderick Inch of Water you ought to allow twelve Lines in Diameter, that giving half an Inch ought to be eight Lines one Half; and that giving a Quarter of an Inch ought to be exactly six Lines: All which may be found by Calculation.

To use the Instrument, it must be placed, so as that its Bottom may be parallel to the Horizon; and then let the Water of the Spring or Source run through a Pipe into the Gauge, (as by the Figure,) and when it wants about a Line of the Top, open one of the Holes (for Example) of an Inch: Then if the Water always keeps the same Height in the Gauge, it is manifest that there runs as much into it, as goes out of it; and so the Spring or Source will furnish an Inch of Water: But if the Water in the Gauge rises, there must be another Hole open'd, either of an Inch, Half an Inch, or a Quarter of an Inch Diameter; so that the Water may keep to the same Height in the Gauge, that is, to a Line above the Holes of an Inch, and then the Number of Holes opened will give the Quantity of Water furnished by the Source or Spring.

The little Vessel receiving the Water running out of the Gauge, is to shew how much Water the Spring furnishes in a determinate Space of Time; for having a Pendulum, which swings Seconds, note how many Seconds there will be in the Time that this Vessel, set under the Hole, giving an Inch of Water, is filling; and exactly Measuring the Quantity of Water it contains, you may know the Quantity of Water the Spring or Source furnishes in an Hour.

There have been several exact Experiments made upon this Subject, (which have been set down before in this Treatise,) from whence, as has been before observed, one Inch of Water will fill fourteen Pints of *Paris* Measure: But of this so much has been said already that I need not repeat it.

To measure the running Water of our Aquaduct or River, which cannot be received into a Gauge, you must put a Ball of Wax upon the Water, made so heavy with some other Matter, as that there may be but a small Part of the Ball above the Surface of the Water, that so the Wind can have no Power of it.

And,

And, after having meaſured a Length of fifteen or twenty Foot of the Aquaduct, you may know by a Pendulum, in what Time the Ball of Wax will be carried that Diſtance; and afterwards multiplying the Breadth of the Aquaduct or River by the Height of the Water, and that Product, by the Space which the Ball has moved, this laſt Product will give all the Water paſſed in the noted Time through the Section of the River, (as has been elſewhere obſerv'd.)

To come to Example: Suppoſe that in an Aquaduct two Foot wide, and one Foot deep, a Ball of Wax moves in twenty Seconds thirty Foot; which will be one Foot an half in a Second: But becauſe the Water moves ſwifter at the Top than at the Bottom, you muſt take but twenty Foot, which will be one Foot in a Second: The Product of one Foot deep by two Foot broad, is two Foot; which multiplied by twenty Foot, the Length, gives forty cubick Feet, or forty Times thirty-five Pints *French* Meaſure of Water, which makes fourteeen hundred Pints in twenty Seconds: And if twenty Seconds give fourteen hundred Pints, ſixty Seconds will give 4200 Pints, and dividing 4200 by 14, which is the Number of Pints an Inch of Water gives in a Minute or ſixty Seconds, the Quotient 300 will be the Number of Inches, which the Water of the Aquaduct furniſhes. And thus much I thought proper to inſert in this Place, though it be a kind of Repetition of what is gone before. And now I proceed to the Manner and Method of Diſtributing of Water for the Supply of Cities, Towns, Gardens, &c.

Several are the Methods which I have obſerved, that Fountain-Makers, and Water-Workmen uſe in this Affair; but none are ſo exact as thoſe which the curious *Marriotte* makes uſe of.

Hitherto we have treated concerning the Coming in of Water only; it now remains that we treat of the Expence or Going out of it, as it relates to the furniſhing Houſes and Gardens, which depend very much, if not altogether, on the Rules before going.

If, therefore, a Spring ſuch as is that of the Town of *Chelmſford* in *Eſſex*, happens to the Lot of any Gentleman, or of any Society of People in a City, what may not ſuch Perſon or Perſons do, either as to the Supply of Buildings, Fountains, or Caſcades: Since by ſeveral Experiments that have been there made with great Care, that Spring from a five Inch Main, whoſe Content is twenty-five Inches ſquare, produces 12272 Hogſheads, 48 Gallons in one Day; which will be ſufficient for any large Family with their Gardens, &c. or even any Town Corporate, that is not very large indeed; eſpecially if it is conducted into a Reſervoir, and diſtri-

buted

buted as it is occaſionally wanted, into the ſeveral Parts of the Houſes and Gardens of ſuch Places.

It will be impoſſible to calculate the various Uſes to which this Water may be applied, or the Manner how, in as much as it depends on the Sizes of your Pipes, and the Jets or Sheets of Water it is to ſupply; however the following Account may ſerve to give ſome Inſight into what I am now putting down.

Supposing then that you have Cocks to ſupply in the Houſe, two of two Inches Diameter, two of one Inch and an half, two of one Inch, and two of half an Inch; for one or more or theſe Sizes are always wanted.

Suppose alſo that you have as many Pipes to ſupply in the Garden, and that there are Caſcades of thirty Foot wide in Additon to it; the great Queſtion is how big, or, in other Words, how many Inches Diameter muſt a Pipe of Conduct be, that is to ſupply them conſtantly and upon all Occaſions; becauſe it would be a conſiderable Detriment to the Uſes of your Houſe, as well as Beauty of your Gardens, if they cannot be ſupplied all at one Time. Your Method muſt be thus.

	Inches Square.
The Two Pipes of two Inches Diameter each amounts to	8
The two of one Inch and an Half Diameter.	4
The two of one Inch	2
The two of half an Inch	1
Now all theſe added together makes	15
And the ſame repeated makes	30
To which, if you add the Width of the Caſcade of thirty Foot, at half an Inch Thickneſs of Water, which is thick enough, the Account will be	180
In all	210

The Square Root whereof being fourteen Inches and an Half, ſo much muſt the Pipe of Conduct be that is to ſupply ſuch a Demand; and ſo much ought a Spring to give: But as there are few Fountains, which play Day and Night; and as there are few Offices or Buildings that are in continual Want of Water when there is a good

 Refer-

Reſervoir made before-hand, where the Water is to lodge, a Spring of ten Inches will ſupply them all a whole Day; and as they are but occaſionally uſed, ſuppoſe two whole Hours in a Day, (which is generally the moſt that they are,) a Spring of four Inches will be ſufficient; but then the main Pipe which goes out of the Reſervoir muſt be fourteen Inches, as above.

Again it is neceſſary to come to a nearer Calculation than Ordinary where the Springs are but penurious, or you are ſupply'd by an Engine.

It is certain that half an Inch Pipe is ſufficient for moſt ſmall Families, and for all the Offices of a Houſe, except the Brew-Houſe, or Waſh Houſe, which ought to be at leaſt one Inch Diameter; when I ſay half an Inch I mean ſix Lines, which gives but a Quarter of the Water which a Pipe of one Inch or twelve Lines does, which is all I think requiſite to add in this Matter; becauſe every Owner of a Family may by a little Obſervation know what Quantity of Water he ſhall want in a Day or a Week, taking one Time with another, better than any Calculator poſſibly can.

CHAP. XXXVII.

A Deſcription of the Thirty laſt Plates.

Plate XXXI. This Plate is a Plan which belongs to the Perſpective of Plate XXXIII. wherein is ſeen not only the Water, but the Walk on each Side, with the Pedeſtals, which repreſent the Cypreſs Trees, which ſee in the Perſpective, together with the ſquare Troughs in the Hills, out of which the ſaid Water is made by Nature to ſpring out of the Hill, and is delivered after its Paſſage through a Canal of a Length undeterminate over the Caſcade, or Head of Water.

The Plan was originally deſigned for a Gentleman in the Weſt, which might, at a reaſonable Expence, have been executed, and is here produc'd as a Specimen of this Kind of Work. The farther Particulars whereof will be inſerted in the thirty third Plate, after I have given a ſhort Acount of the next, which relates in a very particular Manner to the Calculation and Expence of Water over the Heads of Caſcades.

Plate

PLATE XXXII. The Deſcription of this thirty-ſecond Plate is more fully found in the Chapter aforegoing, wherein are ſeveral Particulars which relate to the Paſſage of Water over Caſcades, and Sewers of Water, which will there more plainly appear.

PLATE XXXIII. This thirty-third Plate is an Upright and Perſpective of the thirty firſt foregoing; for which I am obliged to my ingenious Friend Monſ. *J. Devoto*, who has made a Collection of Drawings of this, and other Works of this Nature, in a Taſte very agreeable to the Rural Way; I have in this and ſeveral others of my Deſigns endeavoured to recommend a Deſign, which, I am almoſt bold enough to ſay, equals, if not exceeds, whatever has been produced either by the *French* or *Italians*.

THE Hills from whence the Water proceeds, repreſent themſelves at a Diſtance, and are Reſervoirs proper for the Delivery of ſuch Water; of which Hills there are ſome in the Weſt, as well as many other Parts of *England* very ſuitable for ſuch a Purpoſe; of which the *Quantick* and other Hills in the County of *Somerſet* and *Glouceſter* are plain Proofs: And I muſt add that a Deſign of this kind muſt well have fitted the precipitate Falls of *Italy*, *Switzerland*, and other Places.

THE Steps are indeed drawn a little too ſmooth, but if the Water was conducted over a Cataract or rough Caſcade, it would (in my humble Opinion) merit a Place prior to any Deſign produced in this or any Book of Water-works.

PLATE XXXIV. Is an Upright and Perſpective of the Caſcade at *Buſhy Park*, the real Deſign (at leaſt the approved one) of that great *Mæcenas* of his Age, the late Earl of *Halifax*, whoſe true Taſte in rural and extenſive Gardening, I have long ago took Leave to celebrate.

THIS very handſome rural Deſign is ſupply'd by a Branch of the River *Colne*; which, though not affording a perpetual Current, yet is never wanting to give Spectators a particular Pleaſure.

THE Deſign is ſo well known, that I need not expatiate or enlarge upon it; but is, however, of ſo rude and ruſtick a Manner that it may well ſerve as a Pattern or Model to any that ſhall be diſpoſed to make uſe of Water-Works.

THERE is one Thing obſervable in the Judgment of the noble Lord before-mentioned, and which is his not endeavouring to crowd much Wood about this Caſcade, as the *Italians* and *French*

do, inaſmuch as it is in a Country where there is not ſo much Heat as there is in thoſe juſt mentioned; and this Conſideration it is, that has very juſtly been the Occaſion of ſome modern and very great Deſigners in Gardening, to make their Deſigns more open and freer from Cover; becauſe Water, however delightful it is, is apt (eſpecially if in the Shade, and not clear) to detract greatly from the Beauty of it. And this, in my humble Opinion, is a very great Objection to the otherwiſe very pretty trifling Water-Works of my late deceaſed ingenious Friend, *John-Kyrle Ernly*, at *Sandy-Lane*, *Wilts*.

PLATE XXXV. The next Plate I produce, is from the *Italian* Fountains, and is called the Fountain of the Tower, ſituate in the Gardens of the *Vatican* at *Rome*, the Architecture of *Carlo Maderno*, and was, as appears by the Inſcription, erected by that great High-Prieſt *Paulus* V. (*ad augendum Palatii Proſpectus & Hortorum decorem*,) as that proud Gentleman on his Frontiſpiece has it.

THE good natured Reader will be ſo favourable as to obſerve, that I don't produce this Draught out of any great Oſtentation as to its Beauty, but as it ſerves, (being of a *Portico* Conſtruction) as a Forerunner to uſher in the Draughts of ſome of the ſo-much-famed Water-Works of *Italy*.

PLATE XXXVI. The thirty-ſixth Plate is a Fountain upon a a Flat in the Wood, in the Gardens of *Belvedere* at *Freſcati*, belonging to the ſo-much-famed Family of the *Aldobrandi*; which being ſituate in Cover, and of Ruſtick Appointment can't (though ſmall) be an inelegant Figure in Fact.

PLATE XXXVII. The Reader will probably wonder, that I have mix'd this Plan (which is purely *Engliſh*) amongſt the Perſpectives of *Italy* and *France*; but ſo it is, that a Gentleman of pretended Honour, whom I ſhall not Name, gave me great Hopes of copying the Plans of the Water-Works of *Verſailles*; of which I intended to make the 31ſt, 32d, 34th, 35th, and 36th Plates, and to have let this follow them, that I might have made a Parallel of our *Engliſh* Way of Deſign, compar'd with that of *France*.

BUT as that Perſon (after long Promiſes) deceived me, and thereby hinder'd the Publication of ſome of the beſt Things amongſt the *French* Water-Works, I was obliged to give thoſe Plates the Turn they now have.

THE

THE upper Part of the Work may very eaſily be ſeen to be a Sketch of the fine Amphitheatre at *Claremont*, (belonging to his Grace the Duke of *Newcaſtle*) the Deſign of the very ingenious Mr. *Bridgeman*; and the lower Part, where the Water Spouts out, is an Addition of my own, from a Work of that kind that I have done for the Right Honourable the Earl of *Orrery*, at *Marſton* in *Somerſetſhire*.

IN this Compoſition, which I humbly conceive to be the nobleſt of any in *Europe*, may be ſeen a very magnificent Taſte and Way of thinking, and in which I can't help obſerving, that had the ingenious Deſigner had more Room at *Claremont*, he would certainly have made his Water much larger than that little Circular Baſin, which is ſeen therein, and which is very much eclips'd by the prodigious Grandeur of that Amphitheatre. And this I note for the Advantage of thoſe who have more Room for ſuch a Purpoſe: As for the reſt the Plan ſpeaks for itſelf.

PLATE XXXVIII. The next Account to be given of the Plates placed at the End of this Book, is of ſome Deſigns of Water-Houſes, Grots, &c. the firſt of which (Plate XXXVIII.) is amongſt the Deſigns which are brought over from *France*, and carries with it the Title of *Cecropidarum Sacrilega Curioſitas*, or the Sacrilegious Curioſity of the *Cecrops*, Daughters of *Ops* and *Terra*; of whom *Ovid* thus:

- - - - - Nam tempore quodam
Pallas Erichthonium, prolem ſine matre creatam,
Clauſerat Actæo texta de vimine ciſta,
Virginibúſque tribus gemino de Cecrope natis
Hanc legem dederat, ſua nè ſecreta viderent.
Abdita fronde levi denſa ſpeculabar ab ulmo,
Quid facerent: commiſſa duæ ſine fraude tuentur
Pandroſos, atque Herſe: timidas vocat una ſorores
Aglaurus, nodóſque manu diducit: at intus
Infantémque vident, apporrectúmque draconem.

PLATE XXXIX. I ſhall not pretend to *Engliſh* nor enlarge on this Piece, but leave the Determination of the Deſign to the Curious Reader, and proceed to Plate XXXIX. which is taken from the ſame *Le Architect Paultre*, (by Miſtake *la Nautre* on the Plate,) which is alſo from *Ovid. Met. Lib.* III. *ver.* 407. The Deſign is of *Narciſſus* placed in a Nitch, who ſlighting *Eccho*, and falling

falling in Love with himſelf, is drawn above a Fountain with Water ſpouting out of the Heads of Dolphins underneath: Of which *Ovid* thus; and which containing a Kind of rural Deſcription, I inſert at full Length.

Fons erat illimis nitidis argenteus undis,
Quem neque paſtores, neque paſtæ monte capellæ
Contigerant, aliúdve pecus; quem nulla volucris,
Nec fera turbârat, nec lapſus ab arbore ramus:
Gramen erat circa, quod proximus humor alebat,
Sylváque ſole lacum paſſura tepeſcere nullo.
Hic puer & ſtadio venandi laſſus & æſtu,
Procubuit, faciémque loci, fontémque ſecutus:
Dúmque ſitim ſedare cupit, ſitis altera crevit,
Dúmque bibit, viſæ correptus imagine formæ,
Rem ſine corpore amat, corpus putat eſſe quod umbra eſt.
Adſtupet ipſe ſibi, vultúque immotus eodem
Hæret: ut è pario formatum marmore ſignum, &c.

Plate XL. Is alſo another Deſign of *La Paultre*'s, and is the Story of *Meleager* and *Atalanta*, *Ovid. Metam. Lib.* VIII. who is here repreſented with a Shaft of Arrows on her Back. This Deſign whether ever executed by the Architect, or no, I can't tell, is, I humbly ſuppoſe, amongſt the moſt curious of all he deſigned. The Architecture on each Side is regular and juſt, and the rude Arch in the Middle, makes it, I think, one of the beſt Deſigns I have or ſhall produce.

My late good Friend *John-Kyrle Ernly*, at *Whettam* near *Sandy-Lane*, *Wilts*, on the Road to the *Bath*, had a Deſign at the Head of his long Caſcade much like this, which has, in the Opinion of many good Judges, a very good Effect from the Bottom of it, only the Caſcade is too narrow. And this brings me to the chief and beſt of the *French* Deſigns at *Verſailles*, which for Expence or Coſtlineſs exceeds all the Water-Works of *Europe* if not the whole World.

Plate XLI. This forty firſt Plate is taken out of a Collection of *French* Prints ſome Years ago engraved by the beſt Artiſts in the Gobeline Square; and contains a View and Perſpective of the Fountain of the Stars, ſituated in a little Wood; in the Middle of which five Walks meet, which makes a Kind of Saloon of Foreſt Work.

The

The Border of the Fountain is in Part done round with ruſtick Work; but there are between thoſe Works, (fronting the five Walks,) Openings over which the Water falls in the Nature of a Caſcade or River. The Column of Water in the Middle breaks out alſo through a Mole or Heap of ruſtick Stones, as do all the Jets which break out on each Side; and theſe Kinds of Deſigns I produce as the beſt amongſt the Deſigns of the *French*, which are generally too regular and ſtiff, and adorned with too much Art.

Plate XLII. The forty-ſecond Plate is alſo call'd *La Fontain d'Etoille*, or Fountain of the Star: And an Account of the Largeneſs of the Column of Water *La Montagne d'Eau*, or Mountain of Water at *Verſailles*, and is on the ſame Side as the Theatre, in a little Wood in the Middle of five Allies, or Walks, border'd by a Kind of Saloon. The Water which ſpouts from this Fountain, is in the Shape of a great Mole, or Mountain, and falling again five Ways, forms ſo many Rivers, or Rivulets, which fall from the Foot of the Baſin, into Alleys at equal Diſtances; and in the Middle are Rocks which caſt forth Water, very pleaſant to the Curious Beholder.

Plate XLIII. The next Plate I produce is a Perſpective View of the Gallery of Water at *Verſailles*, which being of ſo great a Number of Jets, or Pillars of Water, all in a Row on each Side, ſpouting up between Statues, make no inelegant Figure, though I humbly conceive it is not the fineſt Figure among the Water-Works of *Verſailles*.

Plate XLIV. Is a Perſpective View of the three Fountains in the Gardens of *Verſailles*, and which makes one of the fineſt Sights there, as well for the Diſpoſition of the Water, as the ſituation of the Place itſelf.

This Place is near where there was formerly an Alley of Water arbor'd, or bower'd over, which the *French* call by the general Name of *Burceau*, and we in *England*, Cover'd Walks; but is now laid open in a very elegant Manner; and as the Jets ſpout up both in the Middle and in each Side, (as a Deſign of my own, which I ſhall by and by produce,) it can't but afford a fine View.

Plate XLV. The forty fifth Plate is a Moraſs of Water in the Gardens of *Verſailles*, ſituated at the End of a Flower-Garden, croſſing the Alley of *Ceres* in a little Wood; and is twelve Toiſes,

or ſeventy-two Foot long, and eight Toiſes, or forty-eight Foot wide. It is a Square of Water bounded with artificial Reeds, painted green, which all caſt out Water. At the four Corners are four Swans, which caſt out Water from their Bills. In the Middle is an Oak Tree, which caſts out great Quantities of Water from its Branches; and on each Side of the Walk, which ſurrounds this Moraſs of Water, there is a Cavity, or Buffet, on which are placed gilt Veſſels, and on each Side of them Spouts of Water, which in its Fall cauſes them to Glitter like Silver.

A Design of this Kind I can't but recommend to the Curious, in as much as there is more of Nature in it, than in any of the *French* Deſigns, eſpecially in the Middle of it.

For this Kind of Moraſs, or Fountain, ſet about with Water-Weeds, ſuch as Water-Dock, Plantane, *&c.* being properly diſpoſed in a low wet Place, and in hot Weather, anſwers all the Purpoſes that a Curious Beholder, (and one who makes Nature his Pattern,) can deſire. How well thoſe Kinds of Weeds and Flowers look when placed in the Middle of Water, any one may judge who ever ſaw that ſmall Fountain which is in the Middle of a little Piece of Woodwork in *Trinity-College* Garden, *Oxford*; which, I think, deſerves Imitation by all who make ſuch like Baſins and Contrivances for Water.

Plate XLVI. The forty ſixth Plate is a Perſpective View of the *Baſſin d'Amour*, or *Baſon of Love*, more generally called the Iſle Royal, which is in the Form of a Canal, in the Middle of which is an Iſland ſurrounded with eighty Water Spouts, which playing on all Sides hinders one from approaching it without being wet. It is placed on the Left Hand above the Labyrinth 130 Toiſes long, and 30 wide, and one Fathom deep, without reckoning thoſe Pieces which were laſt made at the farther Ends. But for a more particular Deſcription of this I refer my Reader to the Introduction to theſe Volumes, *Page* 8. theſe being the very beſt Pieces of Water amongſt the *French*. I proceed to thoſe of *Italy*.

Plate XLVII. Is a fine Fountain in the *Eſtenſian* Gardens at *Tivoli* in *Italy*, and is called the *Eagle-Fountain*, on Account of the carved Figures of thoſe Birds, which ſpout Water out of their Mouths. The fine Ruſtick Mole of Stone, with the Water daſhing or falling down on each Side, makes it very delightful not only in the Print, but Travellers, who have ſeen it, ſay, that in

Fact

Fact alſo, it is one of the beſt Pieces in the Gardens there. It is ſituate in the Middle of a Parterre of Flowers, and the Water plays at leaſt forty Foot high.

PLATE XLVIII. Is a Fountain under a capital Arch in the Palace of Segnior *Maſſini*, the Architecture of the Chevalier *Carlo Fontana*, where the Water ſpouts through the Head of a large *Triton*, who is accompanied by *Dolphins* on each Side.

THIS Kind of Diſpoſition muſt be very ſurpriſing, inaſmuch as it is placed in ſo remarkable a Place as this Arch is; and I muſt own it is very much to be wonder'd at, that ſo auguſt a Deſign as this is, has not met with more Imitators.

PLATE XLIX. Is a Proſpect of the Theatre and Caſcade of Water, which is in the *Villa Ludoviſa*, in the *Freſcati* Gardens; and which, for the Precipitancy of its Fall, and the noble Elegance of its Architecture, ſeems to be ſecond to none of the *Italian* Deſigns, whether we account the Fineneſs of the Bullion or Spout of Water, which plays up in the Middle of the Rock-Work, over which the Water rolls: A noble Elegance of Taſte, in which the *Italians* abound much more than the *French*.

PLATE L. Is a large Ruſtick Fountain in the Garden of Prince *Borgheſe*, without the *Porta Pinciana*, in the Front of the Gate, at the End of the Walk of Elms, and is called the *Fountain of the Maſque*, the Architecture of *Giacomo Antonio Venſanti*. On this Fountain, which has an Arch under the great Maſque, (through which the Rows of Elms may be view'd,) is ſeen lying one of the Sea Gods, pouring out of Water through an Urn, encompaſſed about with large Moles of rude unpoliſh'd Stone, through and over which the Water riſes and falls in a very ſurpriſing Manner. This, as well as many other Pieces of their Water, is a true Specimen of the *Italian* Taſte, which is not made up of Gewgaws and Trifles, as ſome in other Countries are.

PLATE LI. Is another Ruſtick Fountain in the Theatre of the *Villa Aldobrandina*, in the *Belvidere* Gardens at *Freſcati*, which has Water-Works in the Stairs.

I SHALL not take upon me to make any Enlargement on this Deſign, although its Situation, which is amongſt very large Trees, ſeems to make it look very rural.

PLATE LII. Is a Fountain in the Walk in the firſt Wall, which leads up to the *Franciſcan* Cloyſter, the Architecture of *Giacomo della Porta*, and is by ſome ſaid to be the fineſt Sight of all the Water-Works of the *Freſcati*, though I muſt own that there is nothing in the View of it in the Print, that ſeems to promiſe ſo great a Character, the moſt that one can collect from it being chiefly an Idea of ſome fine Grotto.

IT is, as appears by the Inſcription, not of a very antique Erection, no other than of *Clement* VIII. *Anno Domini* 1603. At each End, where the Riches are, there appears to be two Bathing Rooms, and the whole Piece being of the Ionic Order, is in all Likelihood no inelegant Entertainment to the curious Traveller.

PLATE LIII. Is the Fountain of the Gallery in the Gardens of *Belvidere*, in the Palace of the *Vatican*, belonging to the Great Pontiff at *Rome*, the Architecture of *Carlo Maderno*. As for the farther Deſcription or Account of it, with the Judgment which is proper to be paſs'd on a Deſign of this Nature, I muſt leave it to the Deciſion of thoſe who have ſeen, and conſequently underſtand it better than I do.

PLATE LIV. Is, I humbly conceive, compos'd of as fine a View to a Grove of Cypreſſes, as is to be ſeen in any of the Gardens of *Italy:* But what makes it the moſt remarkable, is, the two large Moles of Stone, on the Right and Left of the middle Walk, through the Middle of which, a large Stream of Water ſpouts up into the Air, and falls back again over the rude Stones in various Forms. This Imitation of Nature, ſo peculiar to the Genius of *Italy*, is ſo very remarkable, that I can't but with great Humility offer it as a Specimen to the Curious in *Great Britain*.

THIS Fountain is ſituate in the Gardens of the Family *d'Eſte* at *Tivoli*.

PLATE LV. Is a Fountain, or rather Caſcade, or Theatre of Water, which is on the Top of the Hill near the *Franciſcan* Nunnery, in the *Villa Aldobrandini*, or *Belvidere* Gardens of *Freſcati*, which is convey'd to that Place by a Current of Water ſix Miles in Length.

THIS Piece of Water, the Fall of which is at leaſt 8 or 10 Foot high, together with two other Arches and Maſques, appears to be amongſt the Number of the fineſt Water-Works of the *Freſcati*, and

and from which a noble Lord in *Hampſhire* (I mean my Lord *Lymington*) ſeems to take the Model of one he has at *Down-Husband*, near *Whitchurch*, in that County.

THAT Variety, as well as Rurality of Trees, which appears in the Print, to be on each Side of the Caſcade, muſt needs make a great Addition to the Nobleneſs of this Deſign, in which the Architect has followed one of the beſt Copies of Nature imaginable.

PLATE LVI. Is a Fountain which on one Side appears to be upon the Flat in the *Belvidere* Gardens at *Freſcati*, which coming out of the Side of the Hill, and ſet in rural Works, and Rocks of Stone, muſt have all the good Effects that an *Italian* Genius can produce.

THE Branches of Water under the great Arch which is in the Middle, and which falls very precipitately down, together with the *Tritons* and great Maſques of Water which are on each Side, through which the Water runs with great Violence, ſeems much to excel all the Finery and Gaiety of the *French* Deſigns, and the Borders of the Fountain being all of Ruſtick Work, appears to be no inconſiderable Addition to the Rurality of this Deſign.

PLATE LVII. Which is call'd the Fountain of the *Dove* in the *Pamphilian* Palace at *Rome*, may (I humbly believe) be well plac'd amongſt the beſt Pieces of Art (as being the moſt agreeable to Nature) of any that are found amongſt the *Roman* Works.

THE Structure of the whole Fountain appears to be of rough unpoliſh'd Stones, chain'd or cramp'd together with Iron, in a rude, ruſtick Manner; yet ſo as that ſome Footſteps of Architecture are plainly diſcoverable: Of that Number is the Impoſt at the ſpringing of the Arches, and the geometrical Turn of the Arches.

I TAKE it to be a great Pity that there are no more Books extant, and that ſo many Noblemen and Gentlemen that travel into thoſe Parts have brought no better Account as to the Extent and Proportion of theſe Structures; however, this Effect I hope theſe Endeavours of mine will have, that upon a View of theſe cheap and uſeful Beauties, Rural Architecture will get Footing in theſe Kingdoms, as well as other Countries leſs able to perform them than we are.

PLATE LVIII. Is the Fountain of the *Sybils*, commonly call'd the *Great Fountain*, where the Statues of the *Sybils* are in the Niches, on the Side of the Walk of the little Fountains, in the Gardens of

the

the *d'Eſte* Family at *Tivoli*, which in Reſpect to the Beauty and Juſtneſs of the Architecture, as well as the fine Sheet of Water it makes through a Grove of large Trees, may be juſtly plac'd amongſt the moſt curious Pieces of Art in the *Italian* Gardens.

AND here indeed is again viſible, how great a Pity it is, that we have not the exact Dimenſions of this and other Fountain-Works delineated and brought over for our Imitation: Buildings of this Kind in Stone, would be indeed ſome, (though not a very great) Expence, but as we have Plenty of Hedge-Yews ready grown, it would be very eaſy to imitate ſuch a Deſign as this is, in a few Years.

PLATE LIX. ONE of the laſt Plates I ſhall produce, and which will in a very handſome manner compleat this Collection, is a View of the Caſcade under the Organ, in the Plan of the Gardens of *d'Eſte* at *Tivoli*, in which may be ſeen all that can poſſibly be deſir'd as beautiful, either in Art or Nature.

I SHALL at preſent paſs by the Account that might be given as to the Pleaſure of having Organs play'd by Water falling down from ſo great a Height, that being already hinted at in the third Book of this Treatiſe, which relates to Hydraulicks. But whoever views how judiciouſly and agreeably Art and Nature are here mixt together, and, above all, how much of the latter is here predominant, muſt confeſs that this is the moſt ſurprizing of any of the Water-Works of *Italy* yet produc'd.

THIS Caſcade, or Fall of Water, which can't be leſs than 50 Foot perpendicular, breaking out as it does from ſeveral Parts of the Rock, and daſh'd to Pieces in its Cadence, may well be a Surprize to all who earneſtly behold it. It is in this that the Water-Works of *Italy* ſo much exceed thoſe of *France*, even as much as the rude, but maſterly Strokes of Nature, exceed the moſt delicate ones of Art.

PLATE LX. AFTER I have produc'd ſo many noble Drafts and Deſcriptions of Water-Works, it may ſeem a very great Preſumption in me to offer one of my own Invention, which muſt by that great Number of good Deſigns which go before, be much eclipſed; and all that I can ſay in Extenuation of the Plate I offer in the laſt place, is, that it is ſomething like the Water-Works of *Italy*, and that if there is any thing which is valuable in it, it is in a great Meaſure owing to the Idea's I have form'd from thoſe Works.

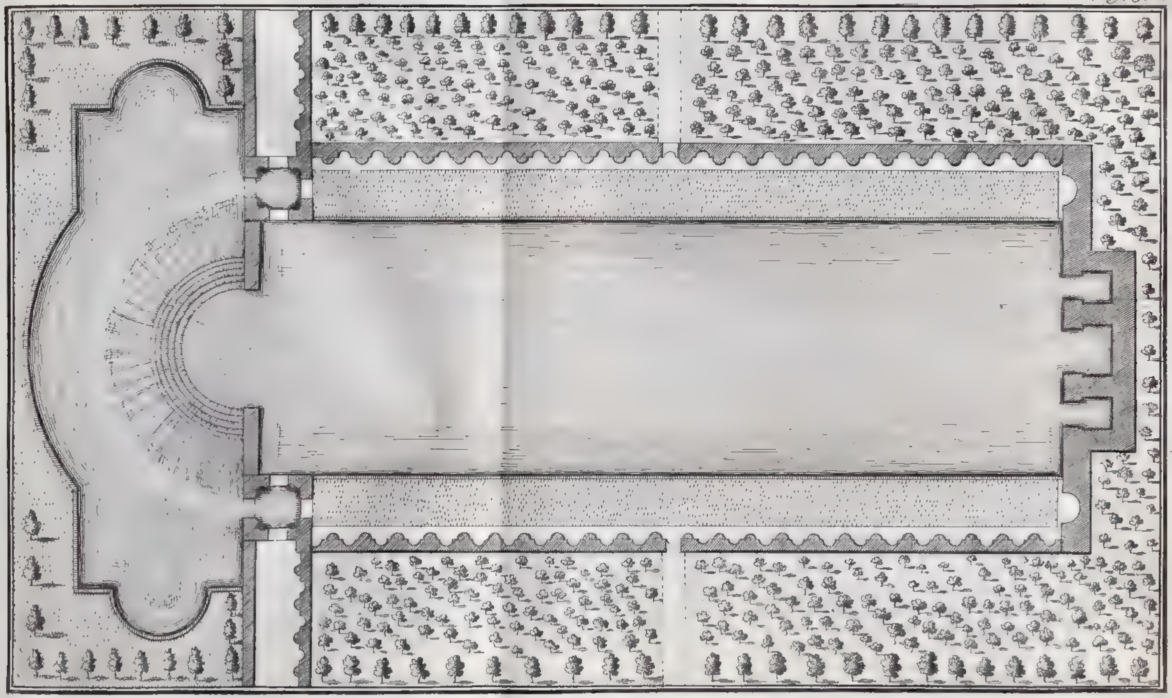
ONE of theſe Kind of Caſcades I have ſometime ſince made at *Spy Park* near *Sandy-Lane Wilts*, on the Left Hand of the Road going to the *Bath*, which though done with very poor materials, yet admits

mits of ſuch a Variety, as ſome good Judges who have been Abroad ſeem to like, and think equal, at leaſt, to any in the *French* Gardens; the Falls of the Water being over Steps and rough Work of different Kinds and different Heights, of about 30 or 40 Foot Fall.

The Deſign here produc'd, was made (though not finiſh'd) for a young Nobleman of *Hampſhire*, ſome little Time ago deceaſed, where the Water indeed is not ſo plenty as it is in the Deſign mention'd in the laſt Paragraph; but the Fall of it is ſhorter, and more precipitate, the Dependance from the Top of the Reſervoir to the Bottom being near 50 Foot, and the Turnings and Windings of the Water, with the different Forms of the Cataracts over which it was to fall, would have produc'd (had it been finiſh'd) all the Variety that ſuch a Place would allow. Nor is this Kind of Work expenſive, the Workmanſhip of the whole rough Stone-Work not coming to above 100 *l.*

At the upper End, above the Baſon, is the Deſign of a Cave, or Grotto at the Foot of the Hill, where *Neptune* is plac'd upon his ouſy Bed, or Couch, and delivering Water to the Falls below, and what would have been very well, was, that at the Bottom of the ſaid Caſcade after the Water had ſhew'd itſelf in this ſportive manner, it was deſign'd to ſupply all the Gardens and Houſe which lie below; and this Supply of Water was to have been from a large Reſervoir on one Side of the Hill, collected from Engines, Rains, &c.

The End of the Fourth Book.



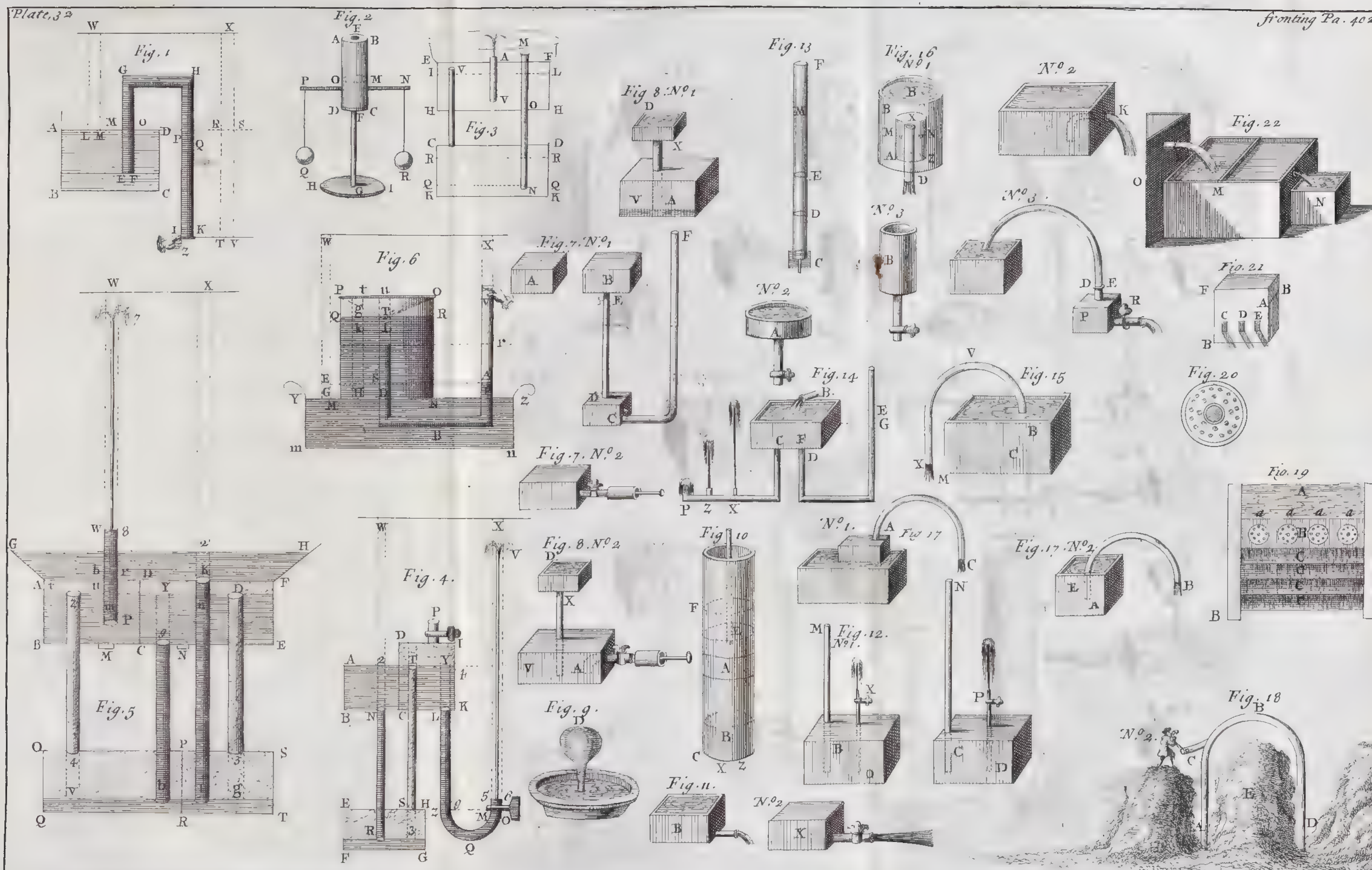
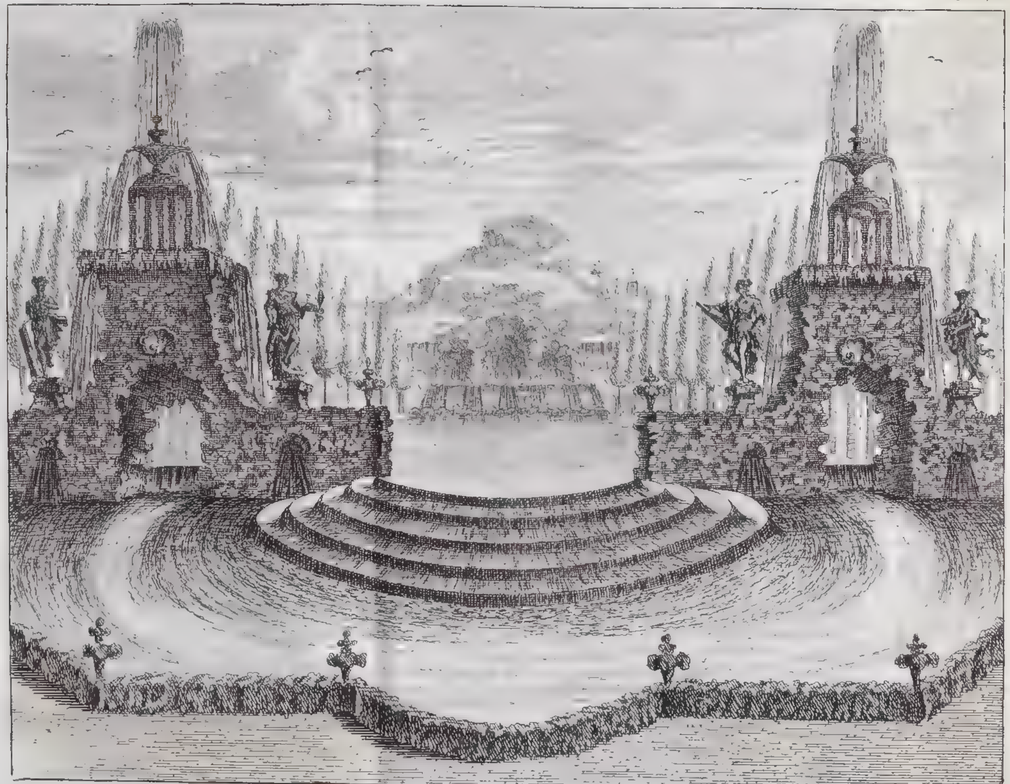


Plate 32
fronting Pa. 402
Fig. 1
Fig. 2
Fig. 3
Fig. 4.
Fig. 5
Fig. 6
Fig. 7. No. 1
Fig. 7. No. 2
Fig. 8. No. 1
Fig. 8. No. 2
Fig. 9.
Fig. 10
Fig. 11.
No. 2
Fig. 12.
No. 1.
Fig. 13
Fig. 14.
Fig. 15
Fig. 16
No. 1
No. 2
No. 3
Fig. 17
Fig. 17. No. 2
Fig. 18
Fig. 19
Fig. 20
Fig. 21
Fig. 22

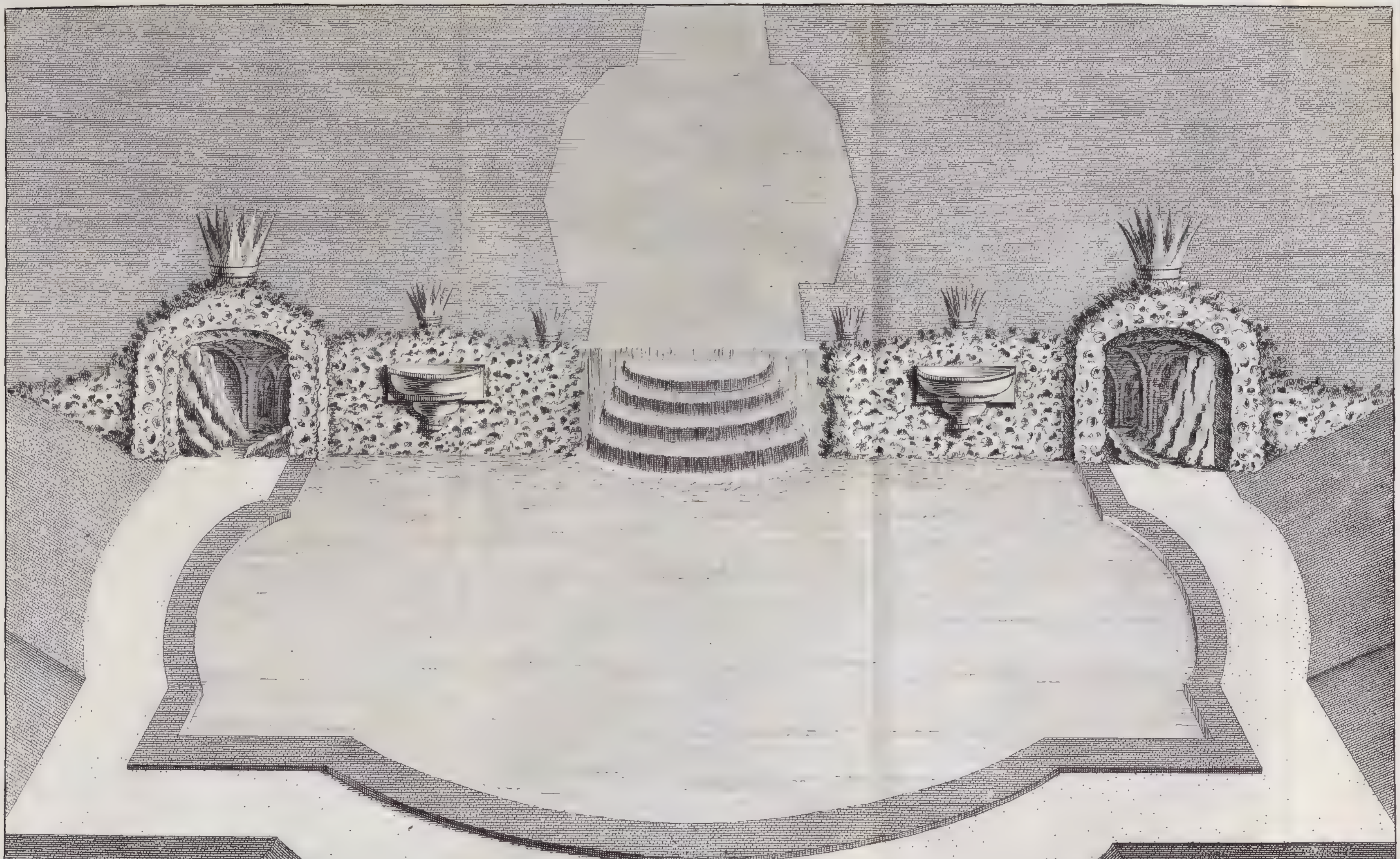
Toms Sculp



Perelle inv. et delin. Toms sculp.

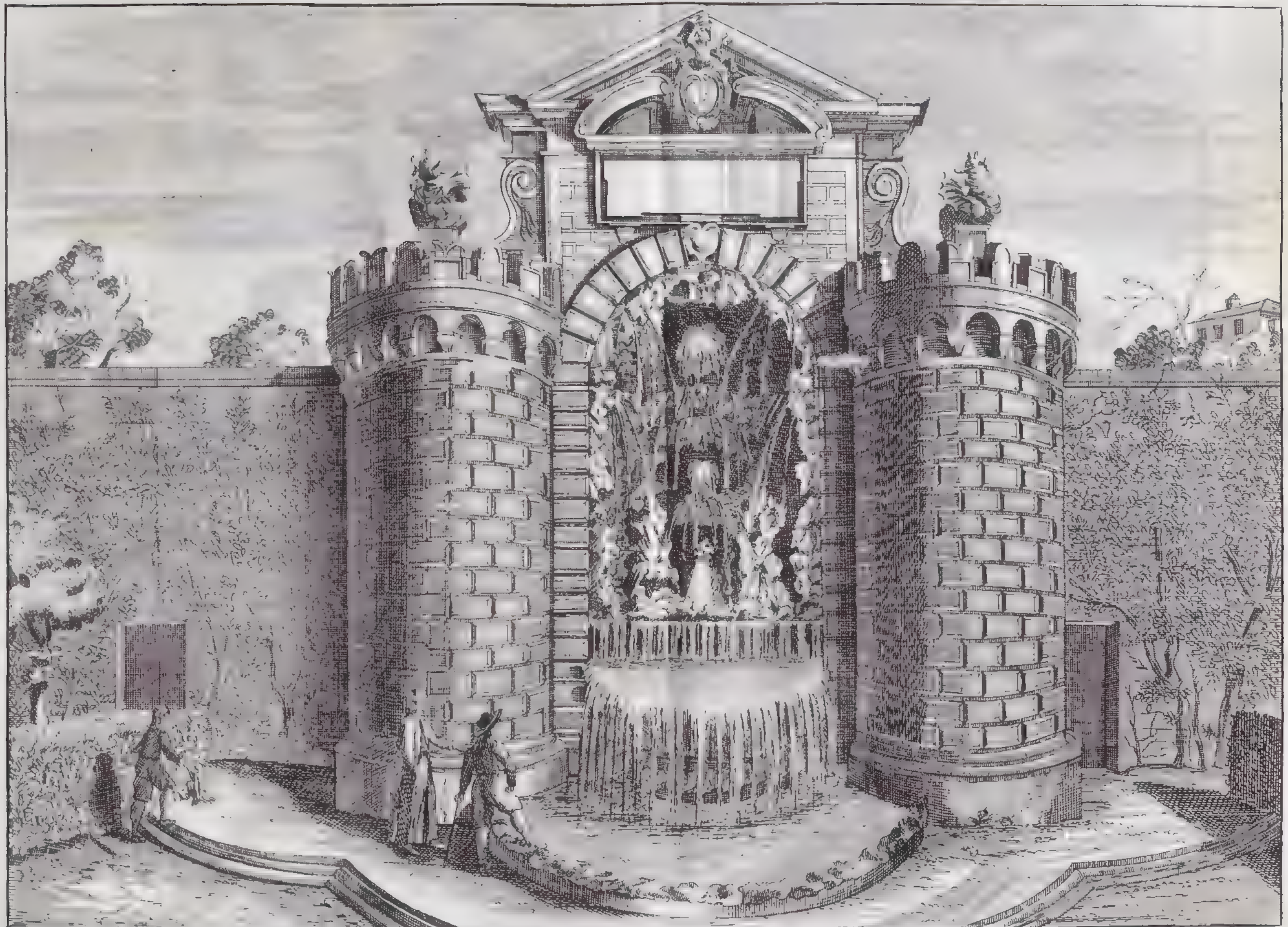
Plate 34

Place this at the End



Toms sculp.

Plate 39



F. [illegible] Font Hill

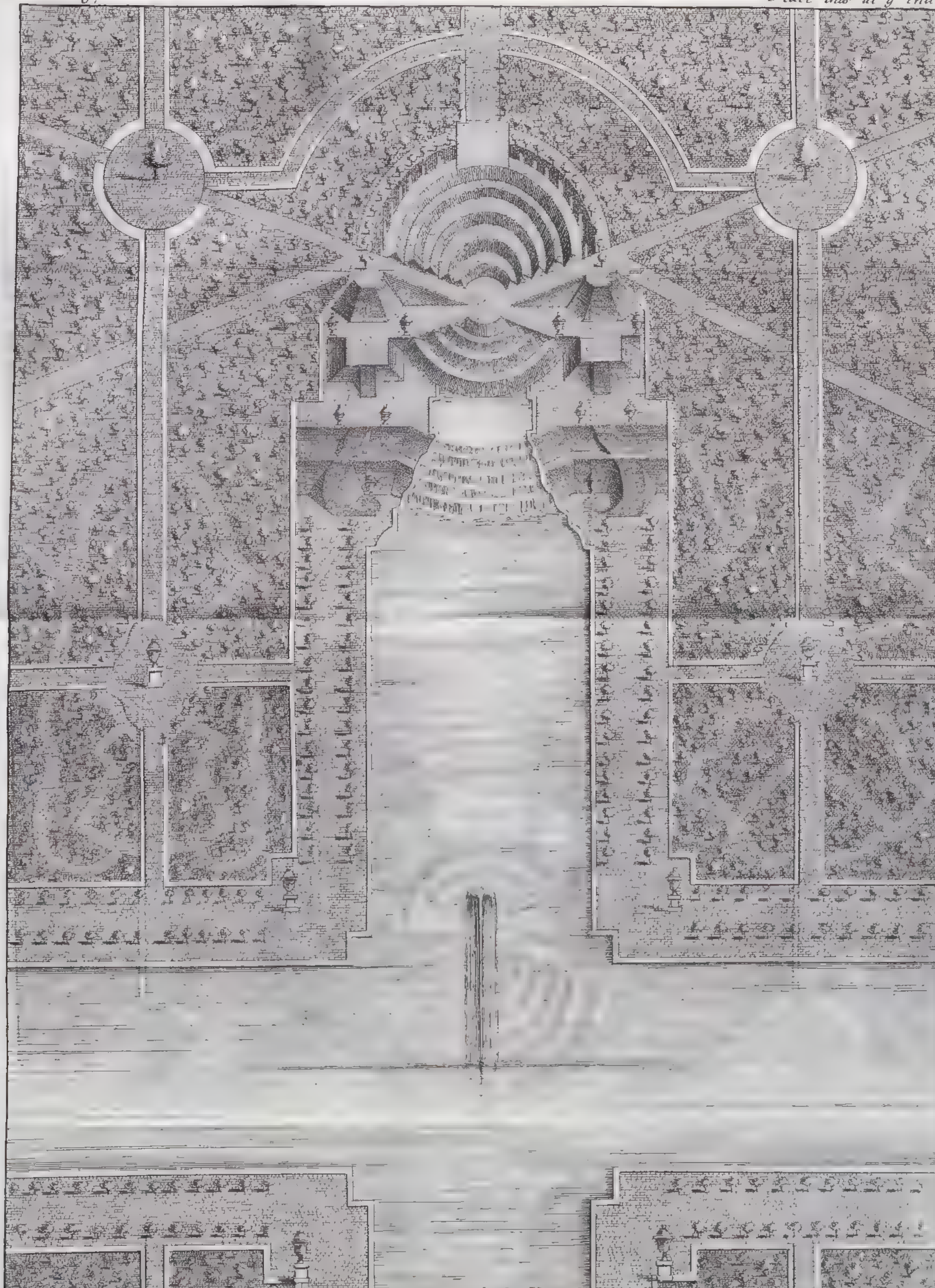
Toms sculpt

Plate 36

Place this at the End

E Collectione Font Ital.

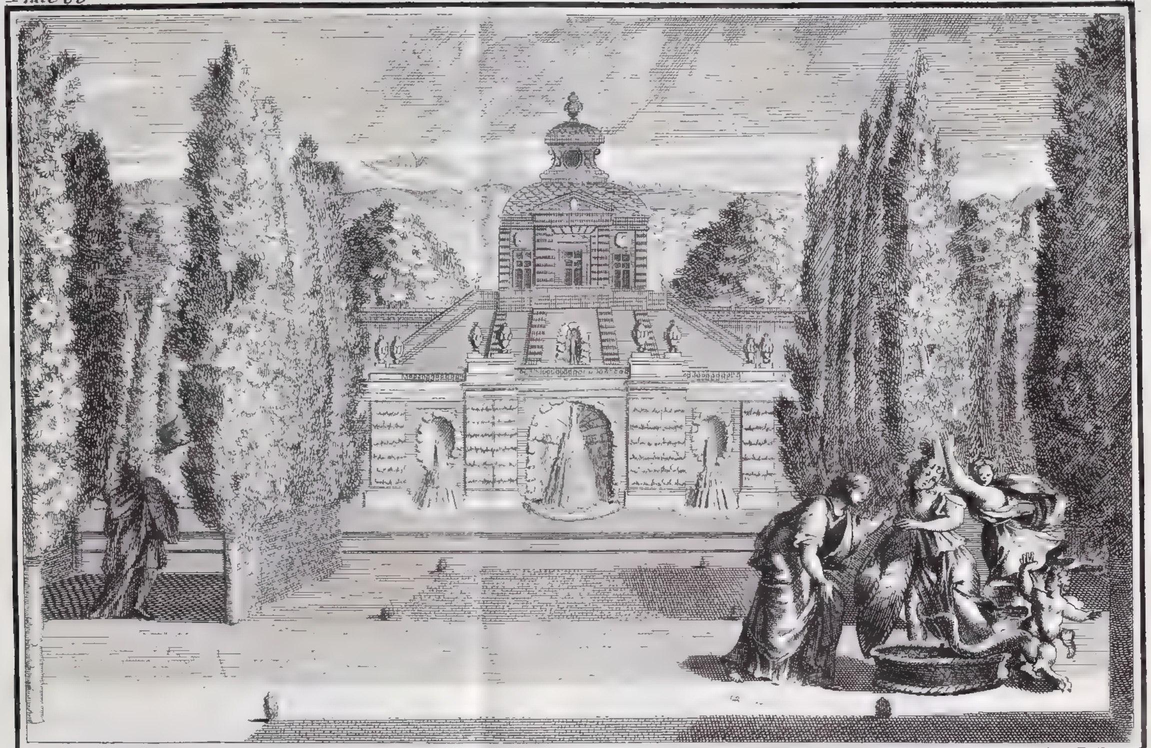
Plate 37 Place this at y^e end



Aut delin Toms sculp

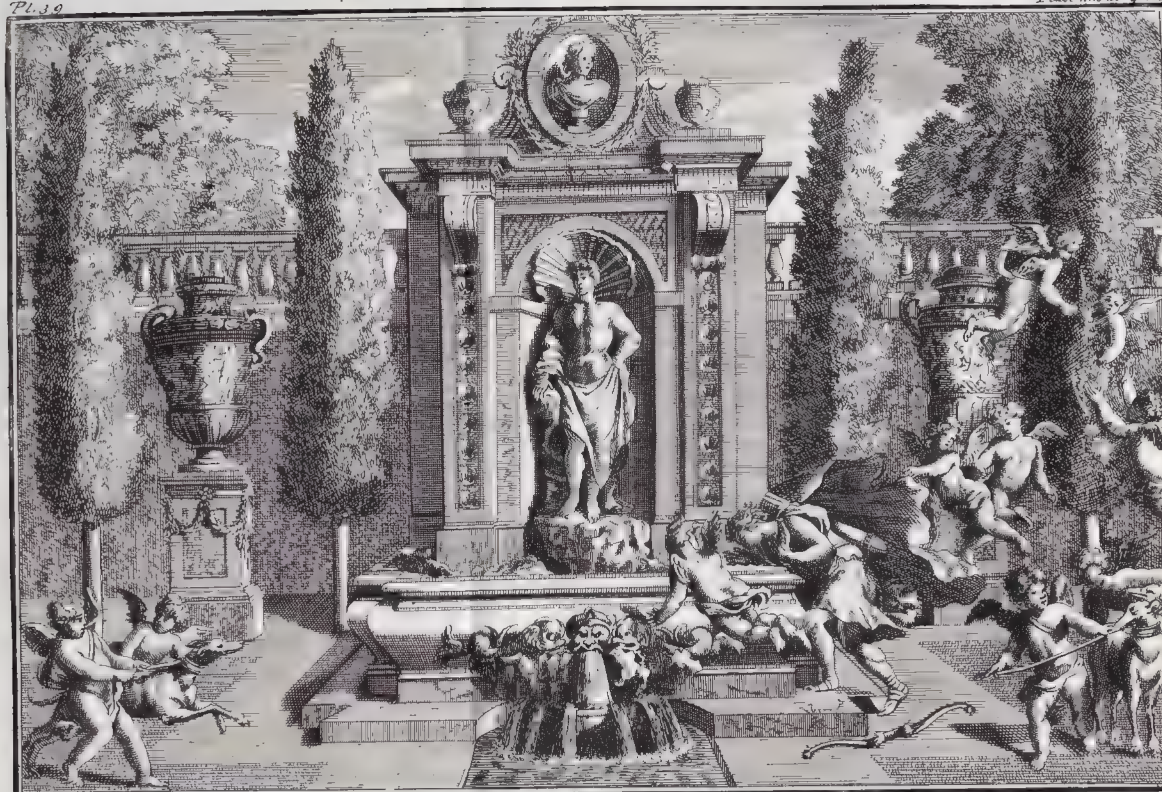
Plate 38

Place this at ye end



La Nautre Inv:

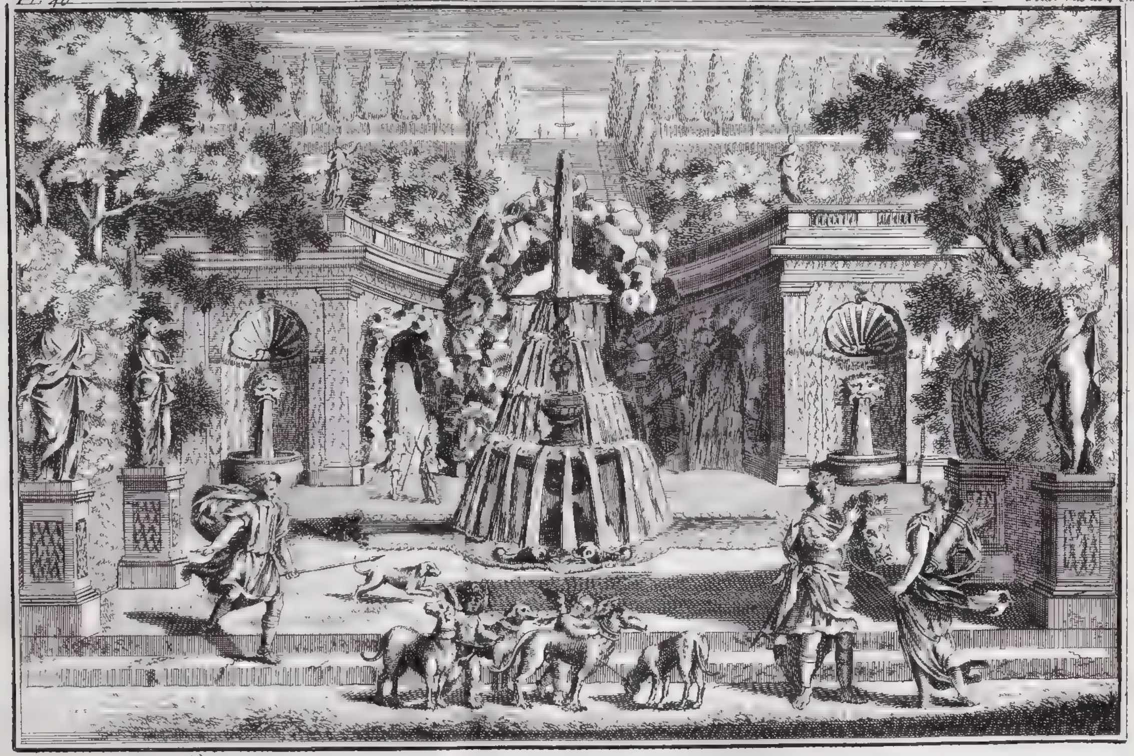
Pl. 39 *Place this at ẏ end*



La Nautre Inv.

Pl. 40

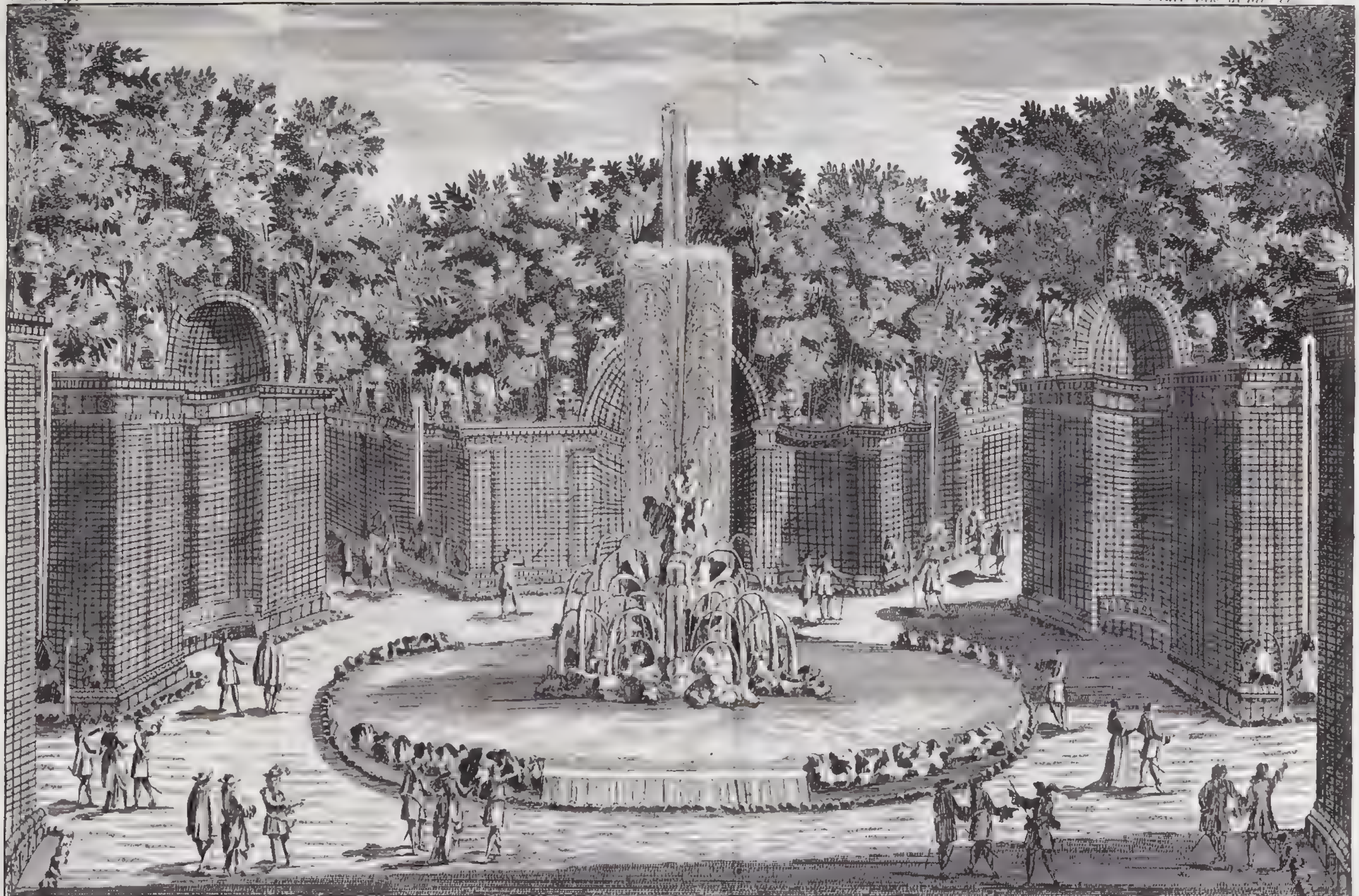
Place this at ẏ end



La Nautre Inv.t

Plate 41

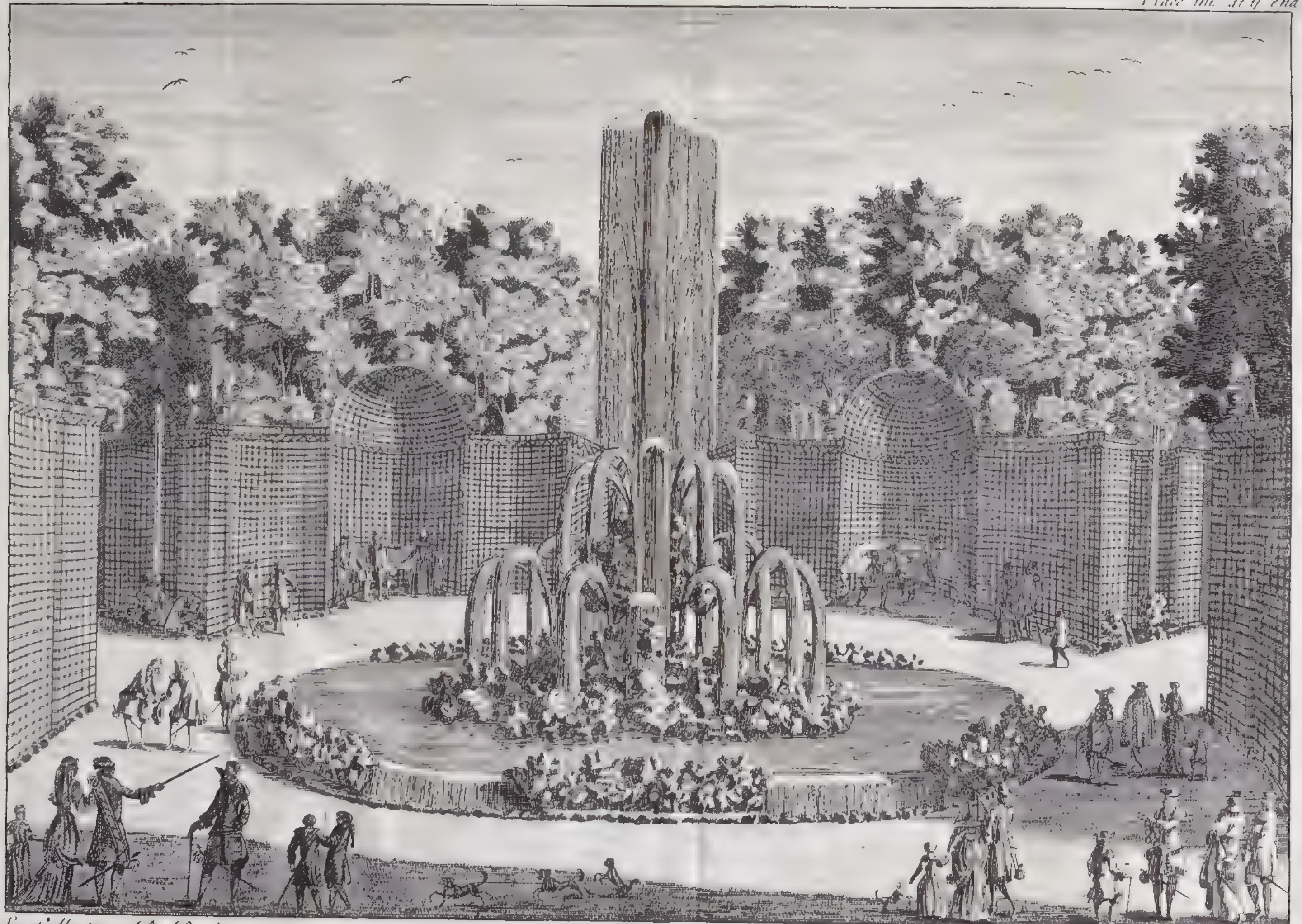
Place this at the end



E. Collectione R. Packer Armig.

Toms sculp

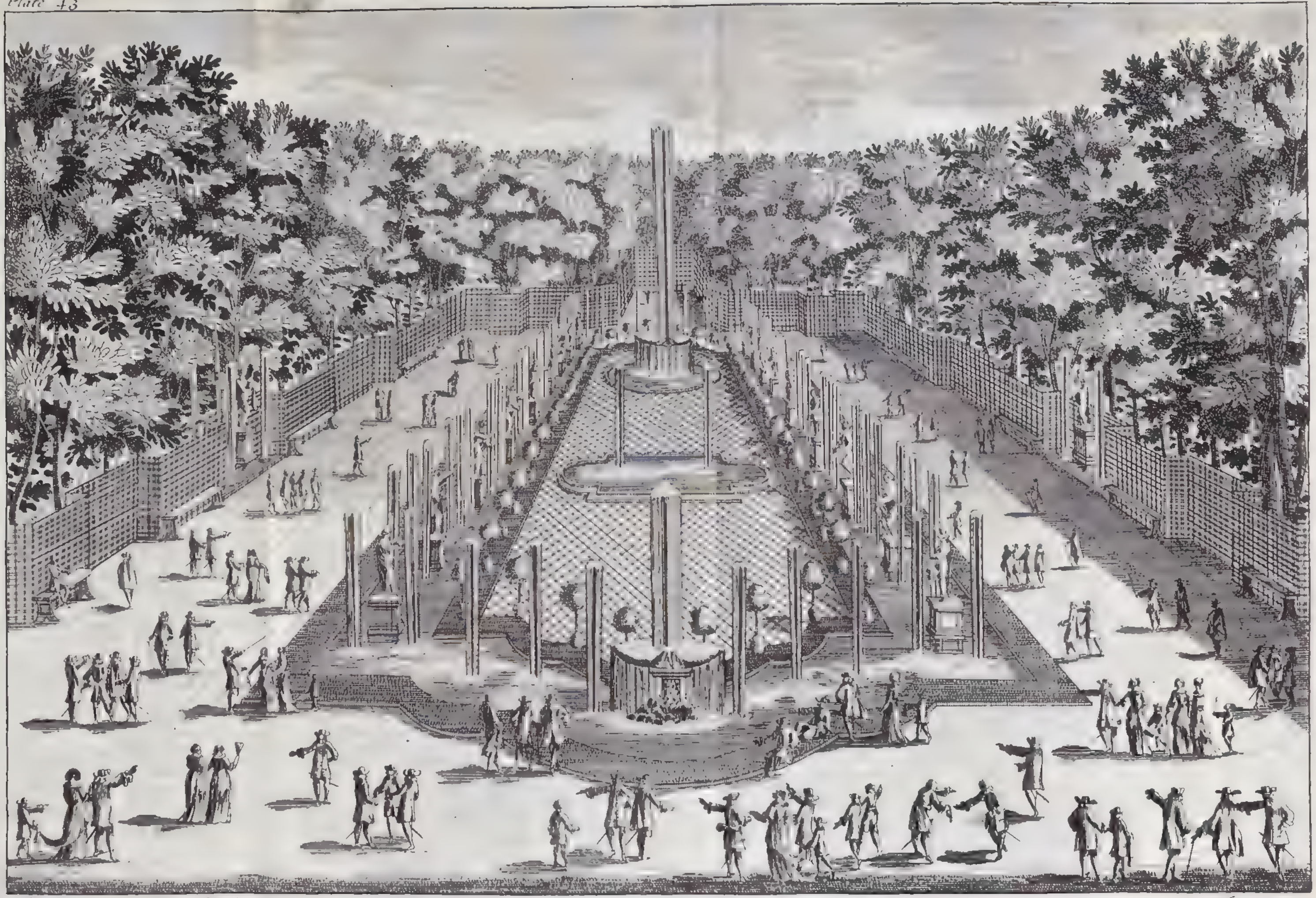
Plate 42 *Place this at y end*



Ex: Collection R: Packer Armig. *Toms sculp*

Plate 43

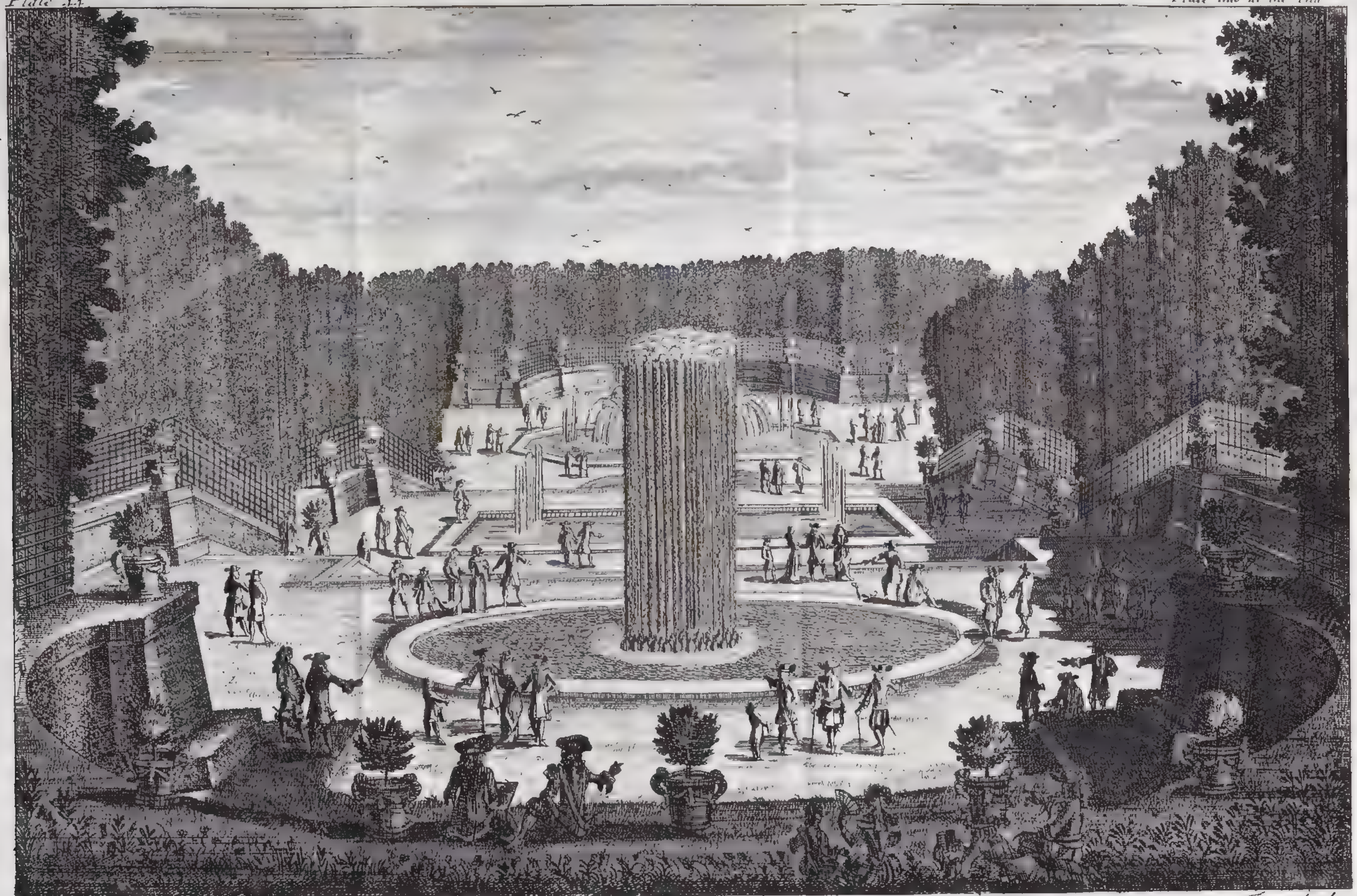
Place this at the end



E: Collectione R: Packer Armig.

Toms sculp

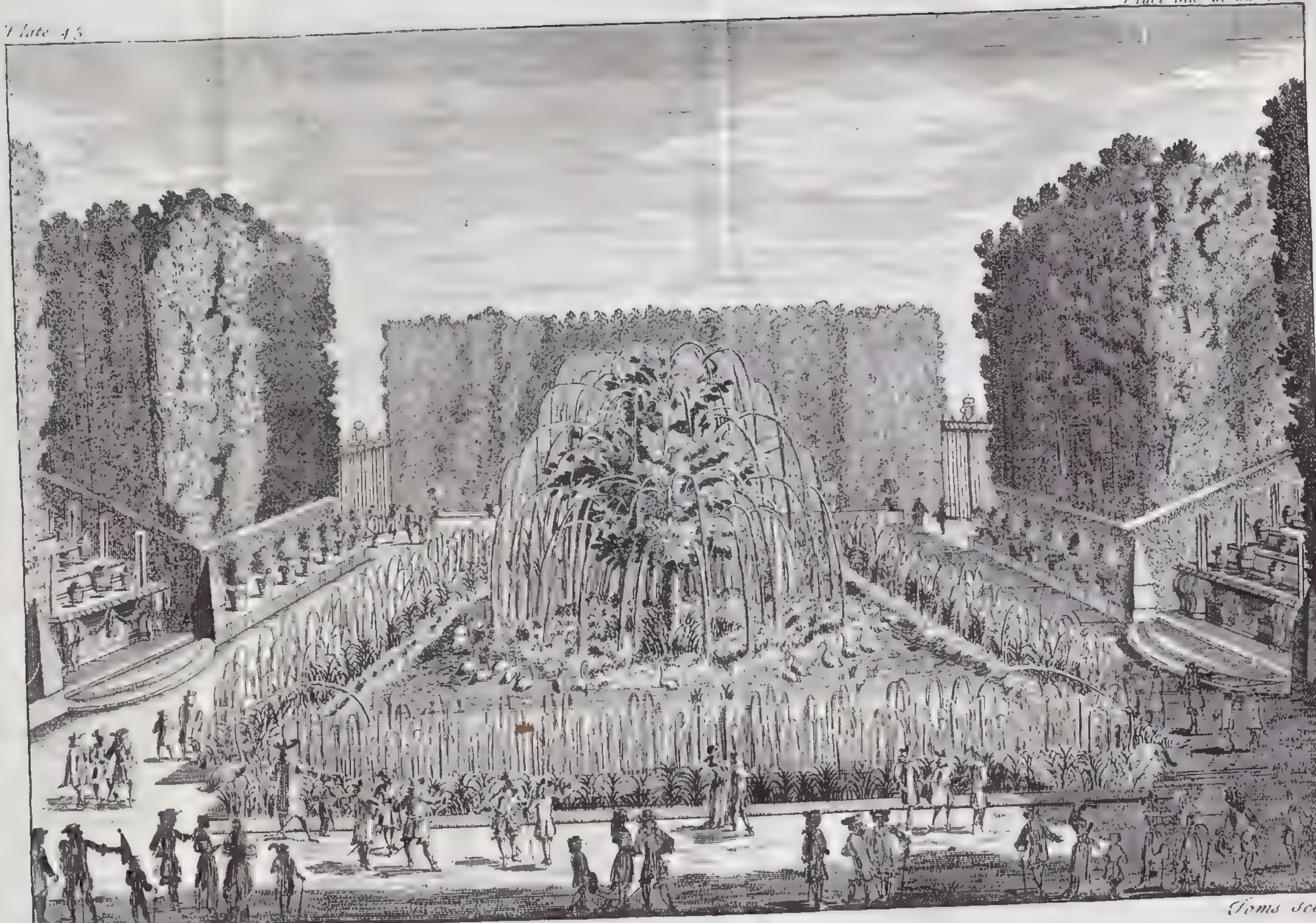
Plate 44. Place this at the end



E: Collectione R: Packer Armig: Toms sculp

Plate 43

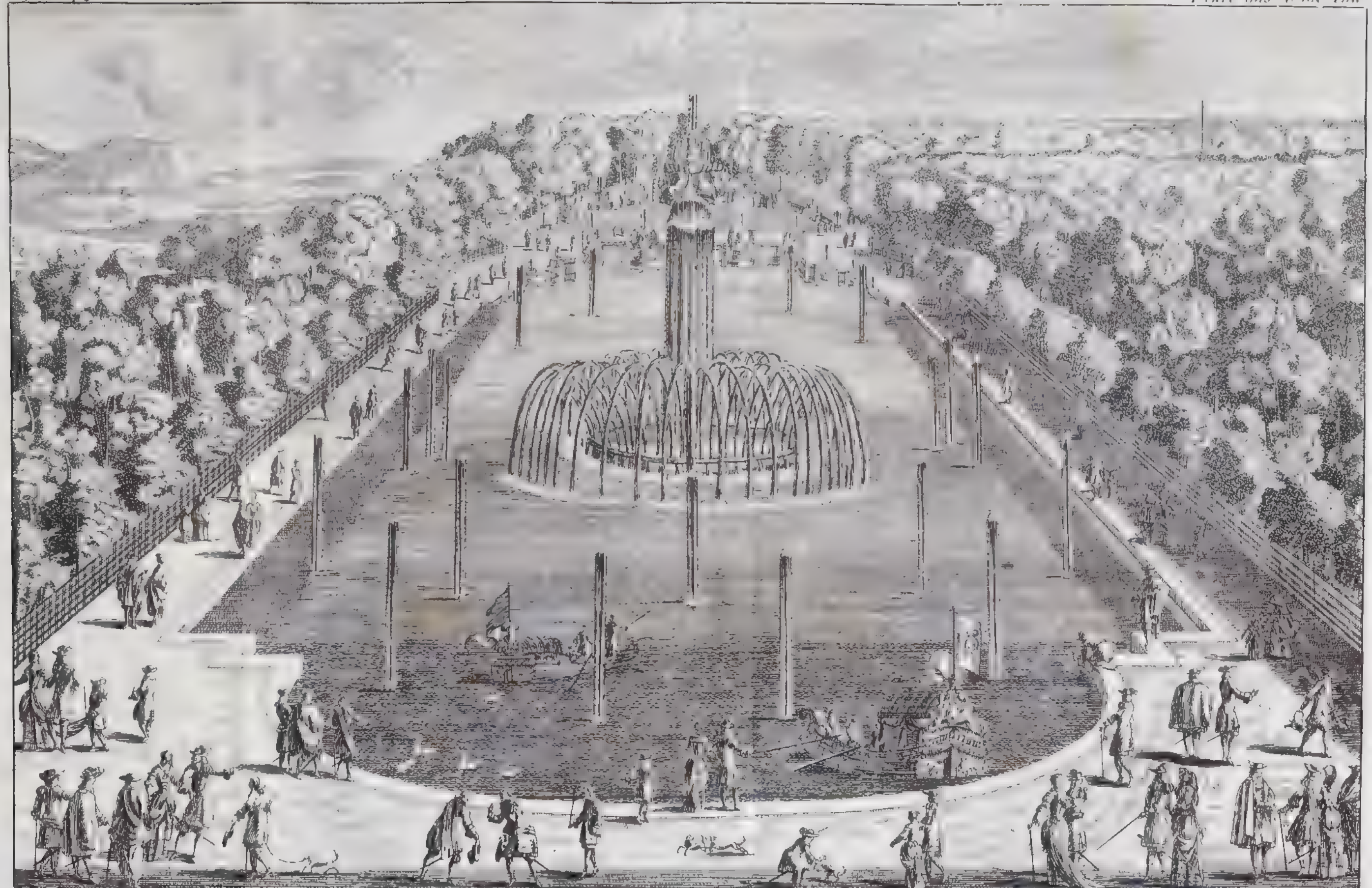
Place this at the end



E. Collectione R. Packer Armig:

Toms sculp

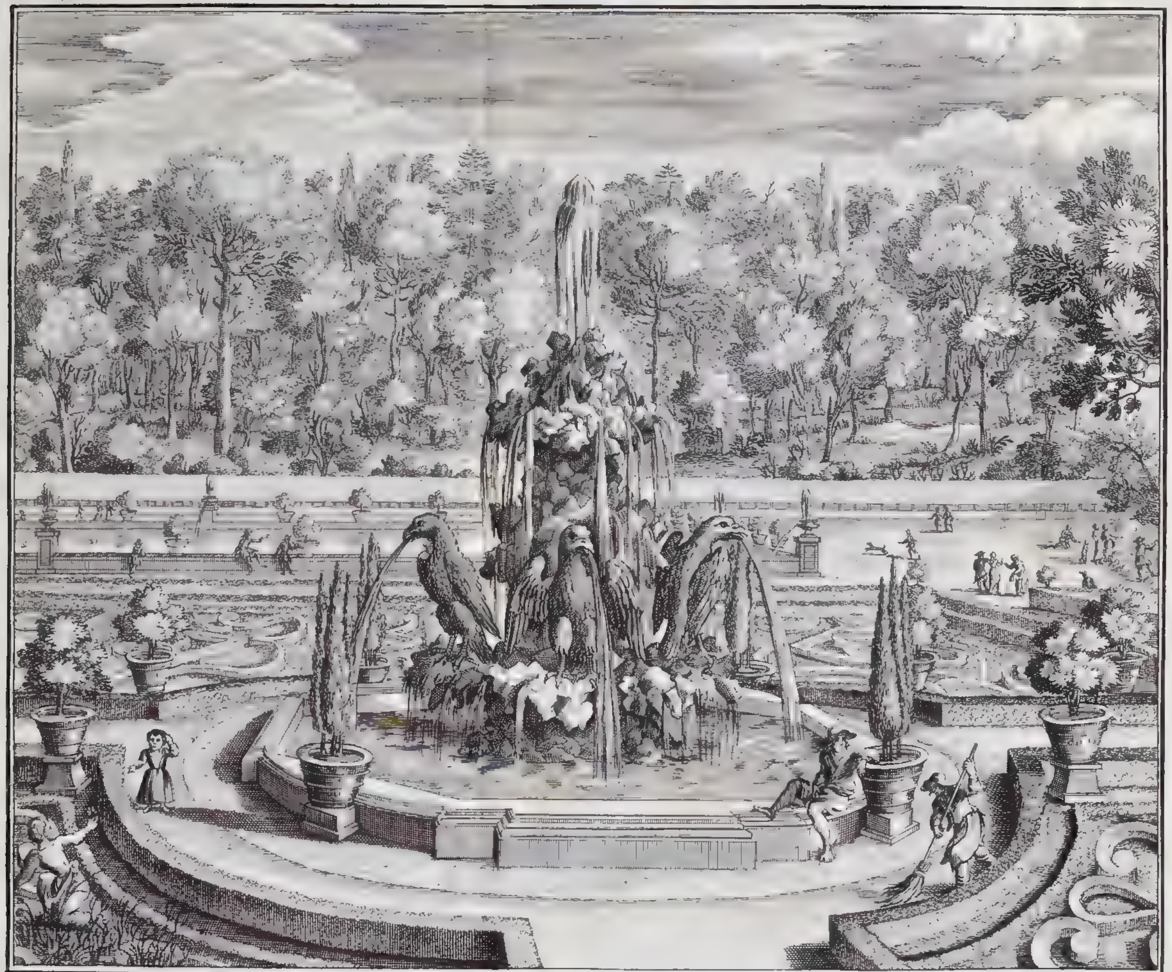
Plate 46 Place this at the end



Ex Collectione R: Packer Armig: Toms sculp

Plate 47

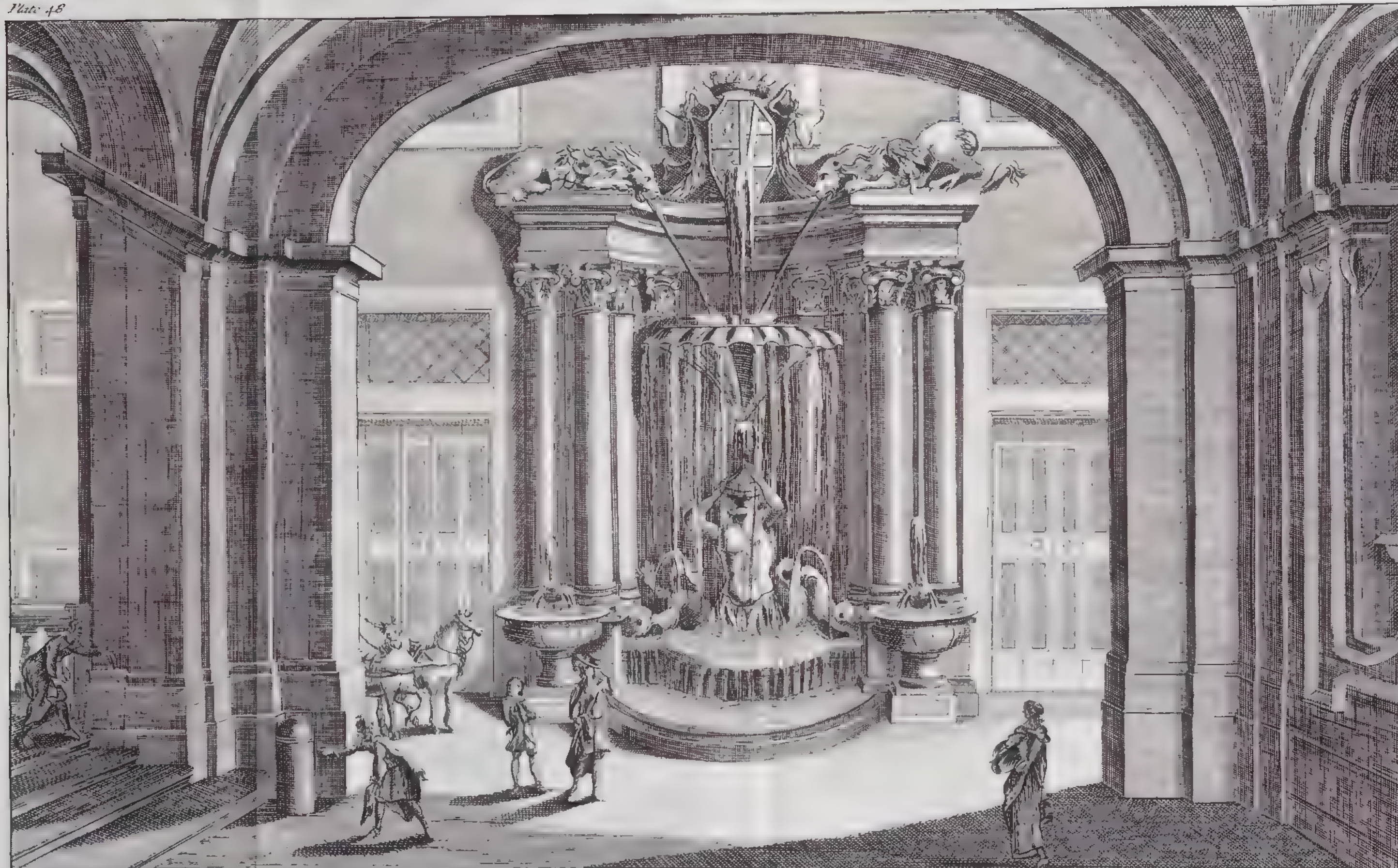
Place this at y^e End



E Collectione Font. Ital.

Plate 48

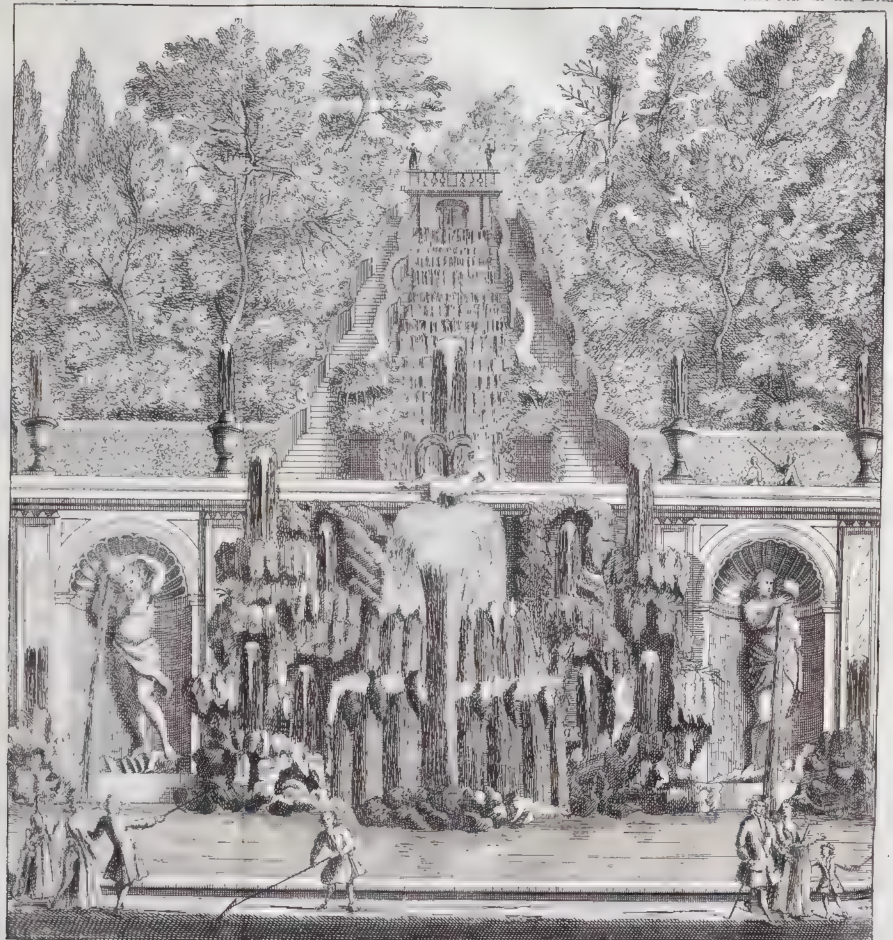
Place this at the End



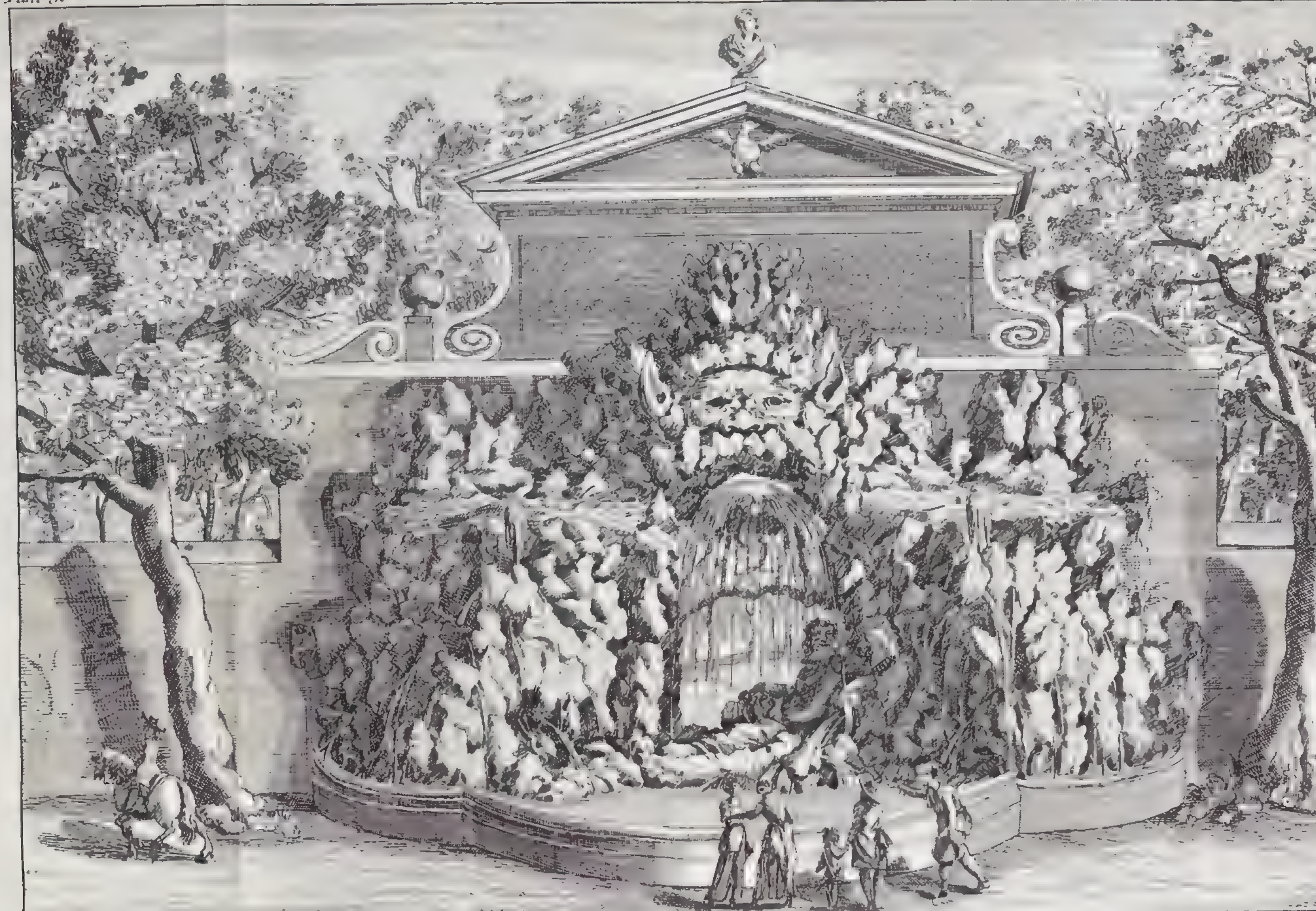
E. Collectione Font: Itat.

Toms sculp.

Plate 40 *Place this at the End*



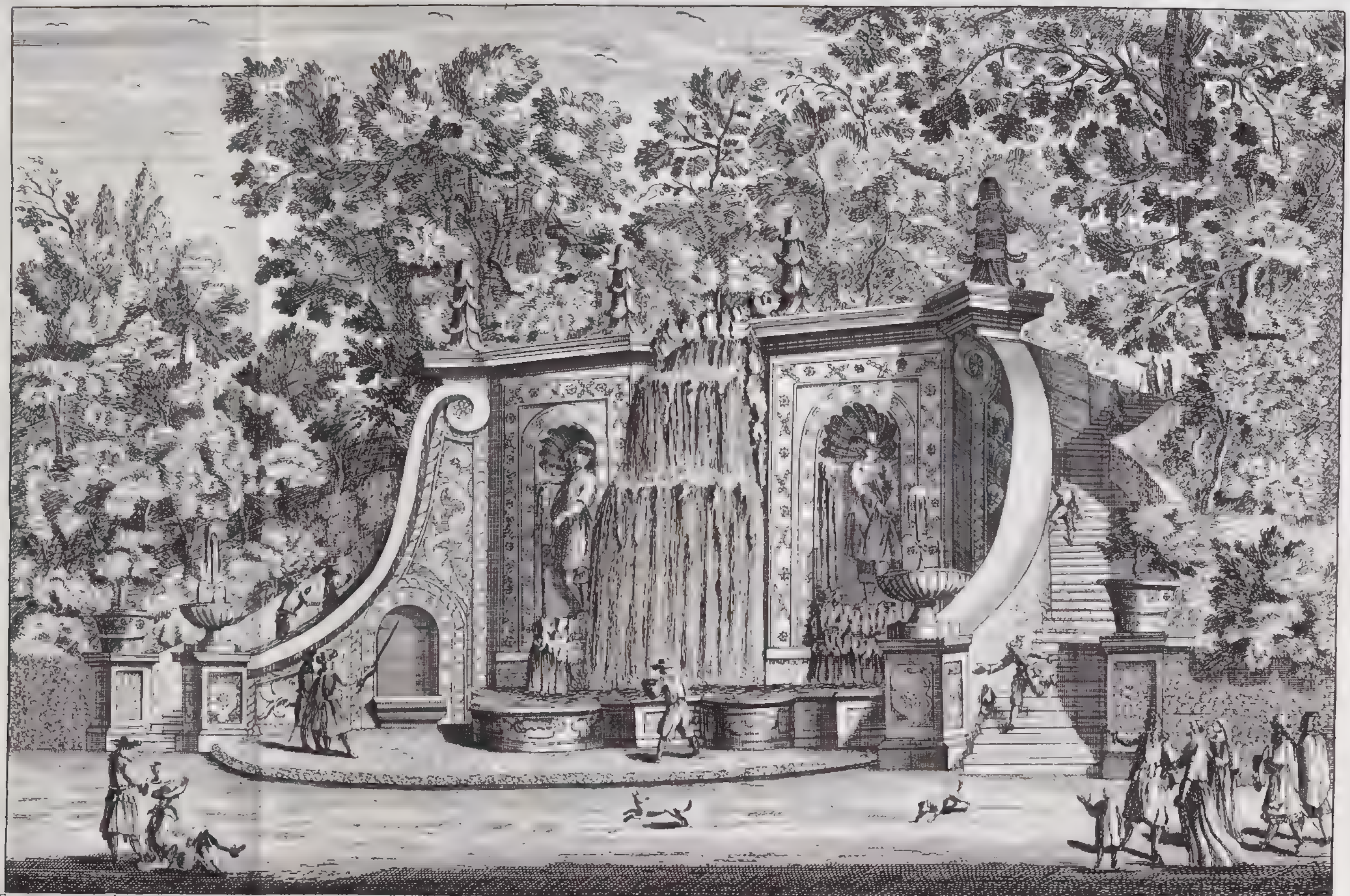
E Collectione Font Ital. *Toms sculp.*



E Collectione Font: Ital:

Fon. sculp.

Place this at the end

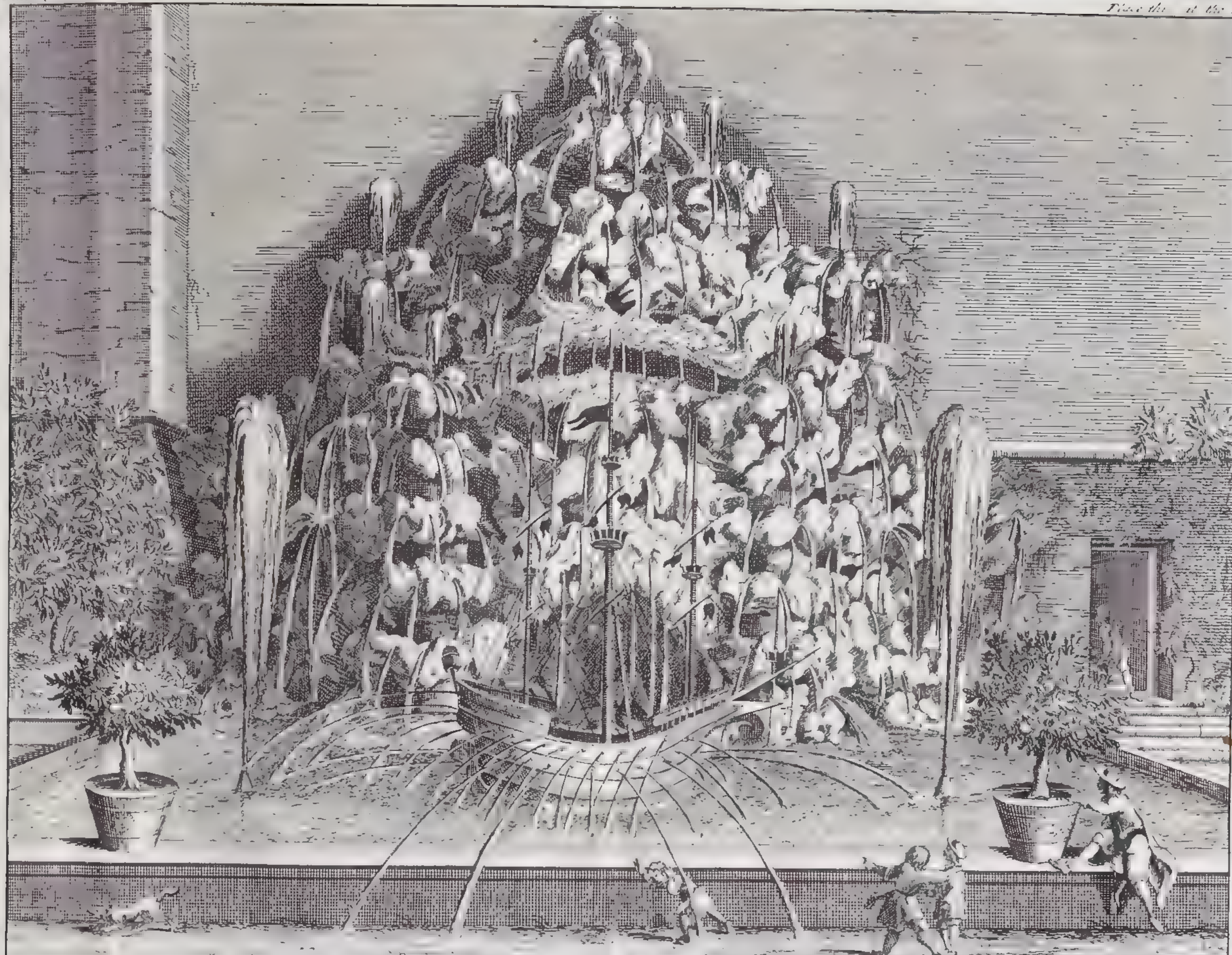


E Couclwni Font. Ital.

Ens sculp.

E. Colectione Font. Ital. *Sims Sculp.*

Plate 53. *Face the [illegible] at the L[illegible]*



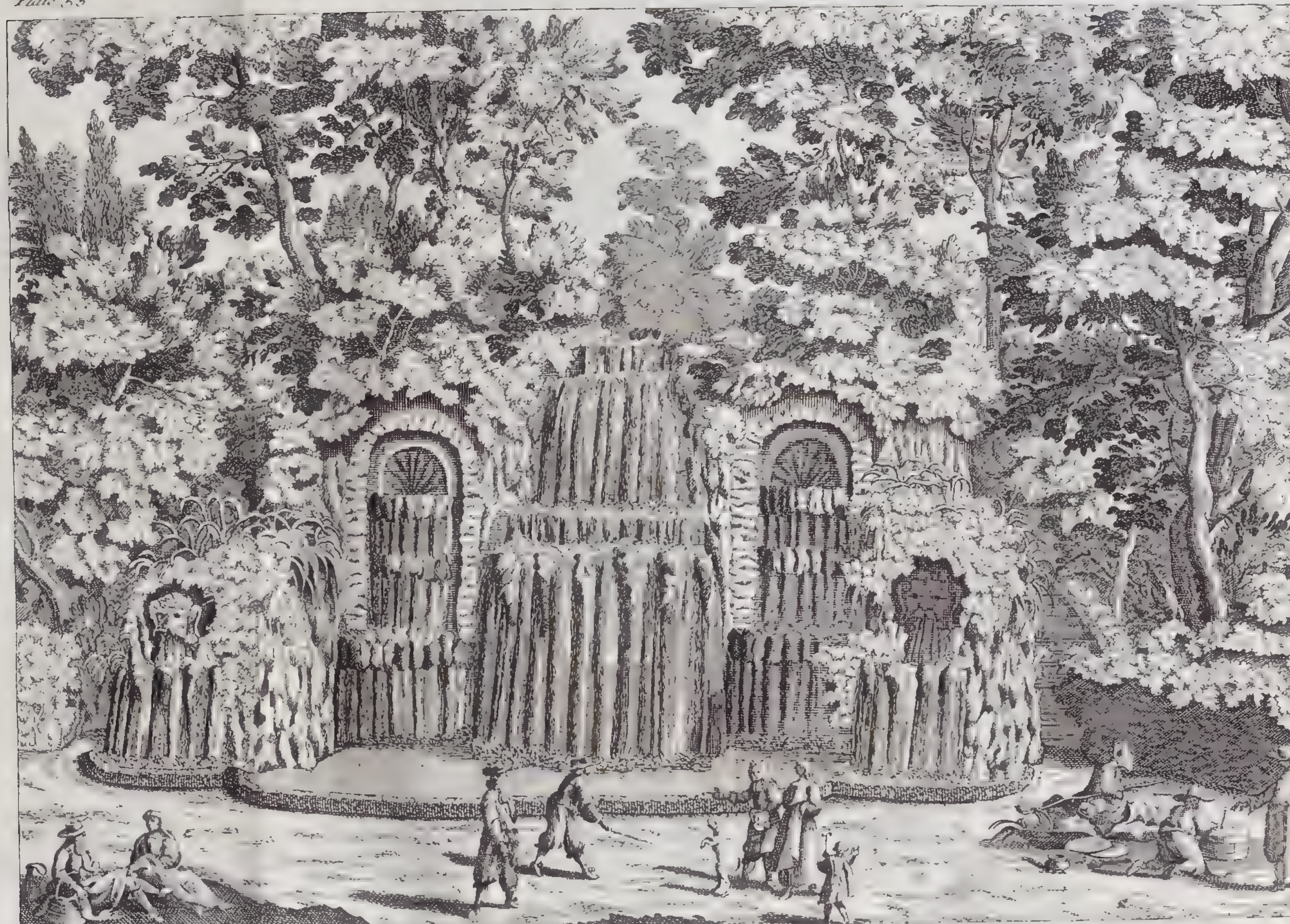
E Collectione Font. Ital *Toms sculp*

Plate 54 *Plate [illegible] Enz*

E Collectione Font. Ital. *Toms sculpt*

Plate 55

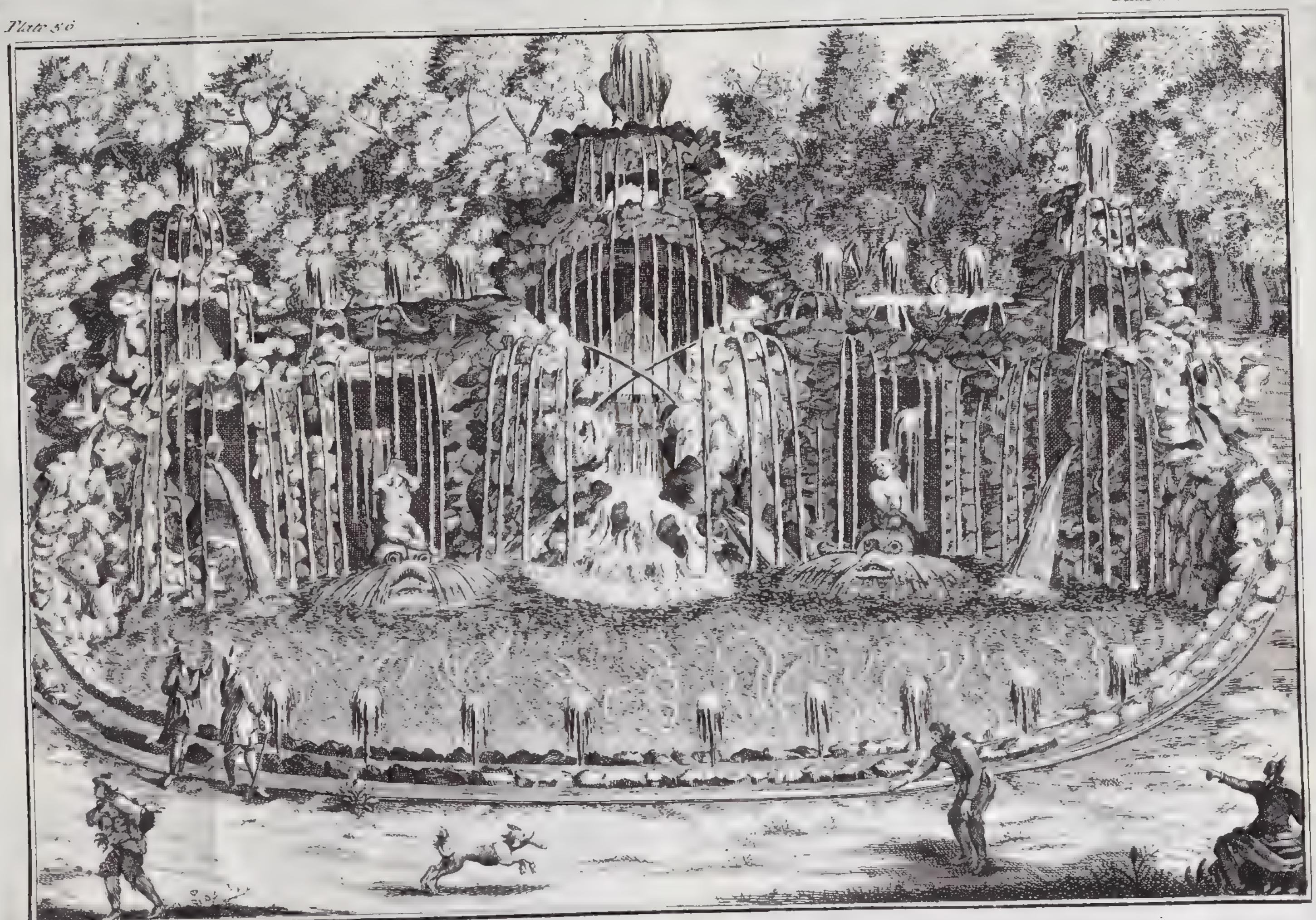
Place this at the End



E Collectione Font. Ital

Plate 56

Place this at the End



E Colectione Font. Ital

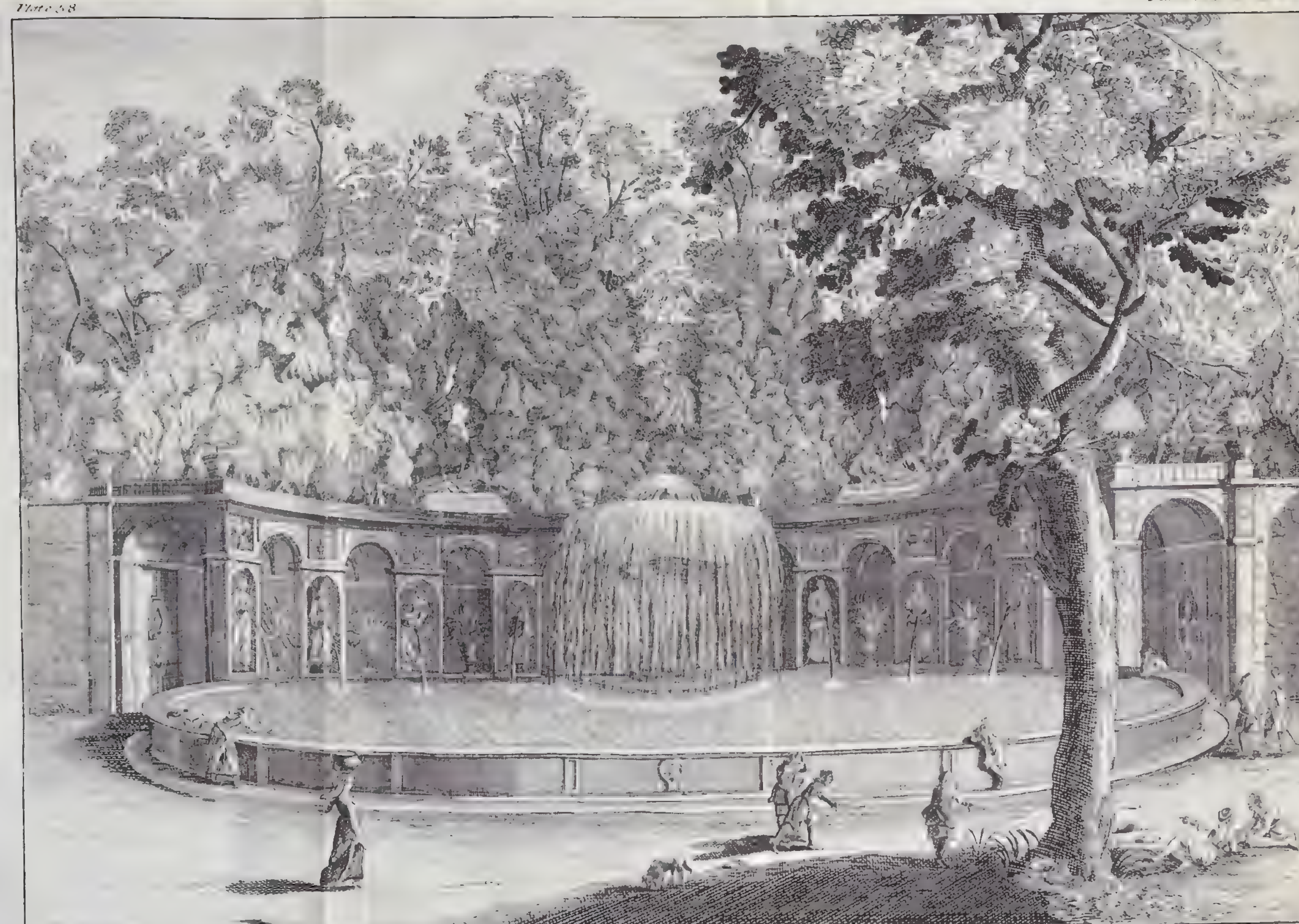
Place this at the End

E Collectione Font: Ital.

Toms sculp.

Plate 58

Place this at the End



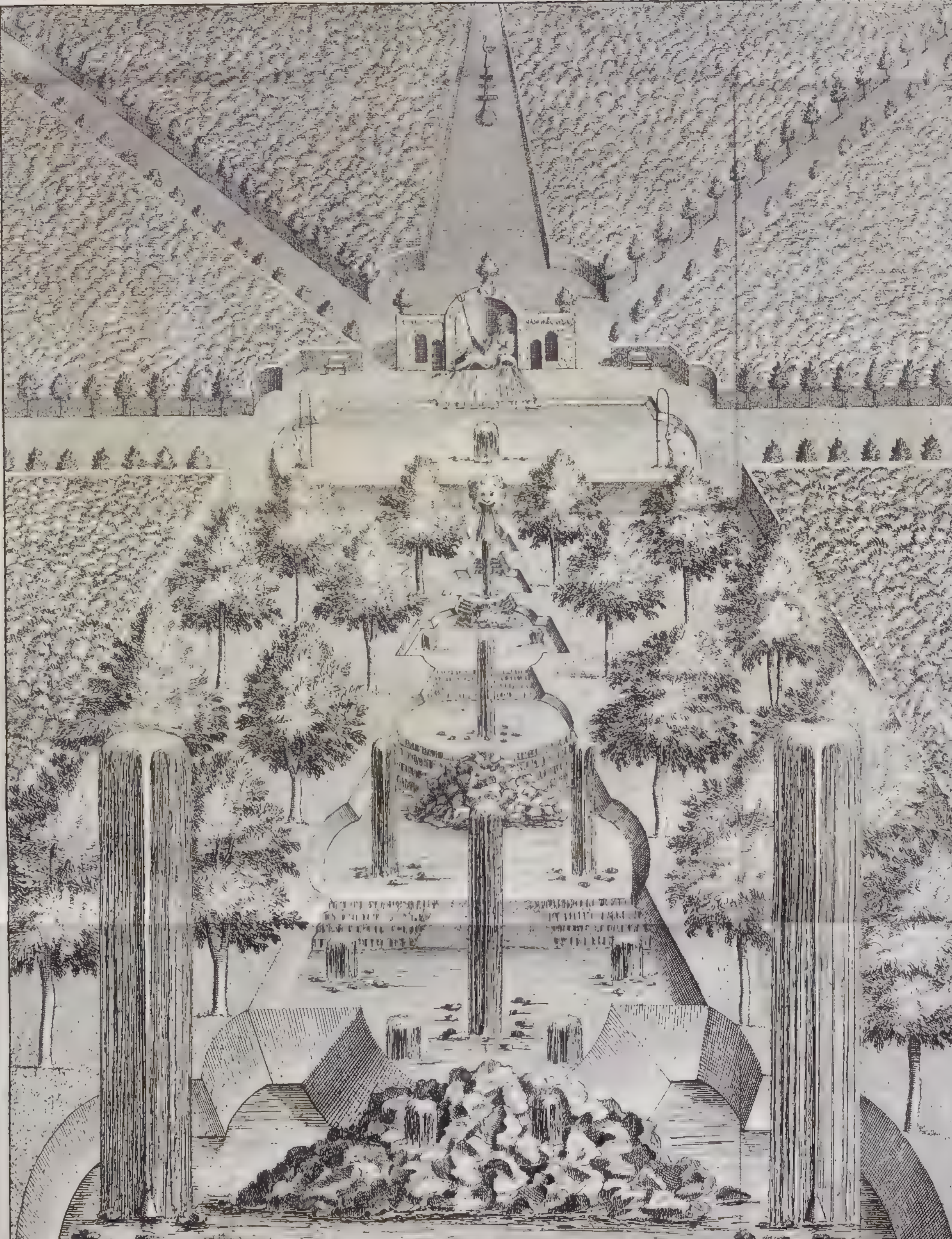
Toms sculp.

F. Guerniero Fecit Inv.

Tonis sculp.

Plate 50

Place this at y^e end



Aut Inv.

Toms sc

NOTES upon BOOK IV.

CHAP. XXXV. PROP. I.

That Air may be compreſs'd, but not Water.

ALL, or moſt of theſe Propoſitions, (with many others to the ſame Purpoſe,) have already been demonſtrated and explained by *Wallis*, *Boyle*, and others, when we have been treating of the Gravity, Elaſticity, and Impulſe of the Air, and other Fluids: But their Truth is laid down by the famous *De Caus*, (with that Plainneſs, Freedom, and Facility,) in his ſhort, but excellent Book *of the Theory of the Conduct of Water*, in the firſt ſeven Pages of it, that I can't but produce it as a brief Capitulation or Compendium of what all the other Authors on this Subject have in their more voluminous Works laid down.

To begin: Let there be two Veſſels, A and B, of one Form, Matter, and Bigneſs, *Vid. Fig.* 7. No 1. *Plate* 32. the which let be full of Water; it is moſt certain, that in either of thoſe Veſſels the Water cannot be preſt, ſo as the one of thoſe Veſſels may contain the leaſt Part that may be more than the other: But when they are only full of Air, I ſay that the ſaid Air may be preſt, and one of thoſe Veſſels may contain more than the other; which ſhall be thus demonſtrated: Let the ſaid Veſſels A and B be made very cloſe on all Parts, and at the Bottom of the Veſſel B, let there be a ſmall Hole E, to which the Pipe ED is faſtened, the other End thereof, D, is faſtened to the upper Part of the Veſſel C, the which is alſo made very cloſe on every Side, and containing about a third Part of the Veſſel B; and to make the Water enter therein with Force, it will be neceſſary to faſten the Pipe F near to the Bottom of the Veſſel C, the which muſt be made as high as may be, that it may give ſo much the more Violence to the Water, which entering the ſmall Veſſel C, will make the Air that is therein, to aſcend into the Veſſel B, which will contain more Air than A, by the Quantity which was in C; and ſo the Air will be preſt in the ſaid Veſſel B; which may be ſeen, if you make a ſmall Hole in the ſaid Veſſel, by which the Air will come forth with Violence. But if you pierce the Veſſel A, there will not be the ſame Effect; becauſe in it the Air is not preſt. But it is here to be obſerved, that although the Air may be preſt, it is but only to a certain Degree, which is about a third Part: And for Proof thereof, if the Veſſel C were as great as B, it were impoſſible that the ſaid Veſſel ſhould be filled with Water, but that the Air will often break forth, and that becauſe B is not capable to contain ſo much Air: Therefore let it be held that the Air may be preſt in a cloſe Veſſel to a certain Degree. There is another Way to force

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the Water with Violence into the ſmall Veſſel, by Means of a Syringe, as in *Fig.* 7. No 2.

Prop. II. *That Water cannot enter into a Veſſel, but there muſt come forth as much Air, except the Water be ſent in by Force.* To demonſtrate this, let there be a Veſſel, as A, *Vid. Fig.* 8, No 1. *Plate* 32. and let the Pipe X be faſtened in the Cover thereof, ſo that it may near touch the Bottom of the ſaid Veſſel; and let the ſmall Veſſel D be faſtened to that End of the Pipe which is without the Veſſel: Then if you pour Water into the ſaid Veſſel A, until it comes to be of the Height V, which is the End of the Pipe, and then the Air being ſhut in the Veſſel A, hinders the Water which is in D, from entering into the Veſſel A. But it is to be noted in this Rule, that if the Water be forced into the Veſſel A with Violence, it may be filled to a third Part, or thereabouts; and the ſaid Violence is cauſed, if the Pipe X be made very long, or if you force the Water in with a Syringe, as hath been ſaid, and as may be ſeen in *Fig.* 2. No 2.

Corol. Prop. III. *It follows, by the contrary Reaſon, that if a Veſſel be full of Water, it cannot be emptied ſo that the Air ſhall not enter therein.* As let the Veſſel or Vial D, *Fig.* 9. *Plate* 32. be propoſed, which let be full of Water, and let it be reverſed, ſo as the Mouth or Neck may touch the Water, which ſhall be ſet under it in a Veſſel; it is certain, that although the Mouth of the ſaid Vial be downwards, no Water will run out, becauſe the Air cannot enter to ſupply the Place of the Water that ſhould run out.

Prop. IV. *There can be no total Vacuity.* This is that which hath been ſaid before, the Proof whereof, may be gathered from the foregoing Corollary, and divers other Examples, whereof here is one: If you have, *Vid. Fig.* 10. *Plate* 32. a Copper Pipe B, whereof the End C is in the Water, and let the other End D be open, to the End that the Peſtle A may be put therein, which will be like to thoſe which are uſed for Pumps and Forcers of Water; and that the ſaid End A, be well environed with Leather, to the End, that putting Water in E, it may not run through to B; then if A be raiſed to the Point B, the Water X, which is level with the Point C, will aſcend to B, to ſupply ſo much Place as is between A and F; ſo the Water aſcends higher than the Level, that there ſhould be no void Place left in B.

Prop. V. *If the Air be preſt in a Veſſel wherein there is Water, and that you give it Paſſage by ſome Pipe, the ſaid Water will come forth with Violence.* If the Air be preſt in the Veſſel X, *Vid. Fig.* 11. No 1. & 2. *Plate* 32. (let it be by Means of a Syringe, or by a Pipe, as hath been ſaid before,) it is certain that then, when the Water hath paſſage, it comes with a great deal more Force than if it came forth from an open Veſſel, as B.

Prop. VI. *If the Water deſcends with Violence into two equal Veſſels, there will enter more Water into that Veſſel where the Water deſcends from the higheſt Place, and the Air will be more preſt therein; and there ſhall be the ſame Rate or Proportion between the Quantity of Water contained in thoſe Veſſels, as there is between the Heights from whence the Water hath deſcended.* Let there be two Veſſels, B and C, *Vid. Fig.* 12. No 1. & 2. *Plate* 32. to which the Water deſcends with Violence by the Pipes M and N, the longeſt of which is N, from whence it follows that there enters more Water in the Veſſel C, than in B; and there is the ſame Rate of the Water D to the Water O, as there is of the Length of the Pipe N to the Length of the Pipe M. And it alſo follows from hence, that in the Veſſel C, where there is more Water, the Air will be more preſt than in B; and the Effects thereof may be ſeen by the ſmall Pipes P and X, of the which two, P caſts the Water higheſt; becauſe the Air is more preſt in the Veſſel C, than in the Veſſel B. In the ſame Manner as before, we may proportion the Air of the two Veſſels to the Heights of the Water

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ſpringing forth by the ſmall Pipes P and X, the which ought to be equal.

Prop. VII. *All heavy Things whatſoever, weigh more in the Air than in the Water.* Although every heavy Body hath always in it ſelf its proper Weight, yet nevertheleſs they are alſo conſidered diverſly, according to the Place where they are placed; as it is certain that Wood weighs nothing in the Water, becauſe it doth not deſcend towards the Center of the Earth, which is proper to all heavy Things; but if it be in the Air, it falls towards its Center with Weight; wherefore we may ſay that it weighs more in the Air than in the Water: And ſo we may ſay of all Bodies, although they are heavier than the Water; for although they fall towards their Center of Gravity in the Water, yet it is not with ſuch Swiftneſs. It is not neceſſary to ſhew here by what Quantity the ſaid Heavineſs is more weighty in the Air, than in the Water; ſending the Curious to the Books of *Archimedes* concerning Things falling in the Water; where it is demonſtrated, that heavy Things weigh more in the Air than in the Water, by the Quantity of Water which is equal to them.

Corol. *It is here to be obſerved, that Waters are of divers Weights; and they ſay, that on the Territories of* Cara *in* Spain, *there be two Fountains, in the one of which, divers Things being put, ſink to the Bottom, which being put in the other, float at Top. They report the ſame Thing of the Lake of* Sodom, *and of the Fountain of* Arethuſa. *The which Effect comes to paſs, by reaſon of the Weight of the Water: And from hence we may infer, that one and the ſame Thing weighs more in lighter Water, than in heavier Water.*

Prop. VIII. *Water weighs upon that which ſuſtaineth it, according to its Height.* I have given this Example, becauſe divers have deceived themſelves upon this Subject, who have thought to raiſe Water, not conſidering the Weight, when it comes to be raiſed very high. That which is then to be underſtood by this Propoſition, is, that the Sucker, *Vid. Fig.*13. No 1. *Plate* 32. being at the End of the Pipe M, to ſuſtain the Water which is within the ſaid Pipe, that the Water weighs upon it according as the Height thereof ſhall be in the Pipe. As let us ſuppoſe that the Water be in the Pipe as high as D, and that it weighs 20 Pounds, if we fill the ſaid Pipe to E, which is as much again, it will weigh 40 Pounds; and if we double it again, it will weigh 80 Pounds: And according to the greater or leſſer Height of the Water within the Pipe M, the Sucker C will be harder or eaſier to lift up, which is that which ought to be conſider'd, when the Water is to be raiſed very high, to the Intent to proportion the Thickneſs of the Pipes to their Height, ſo as the Water that is in them may not be too heavy for the moving Force. It is alſo to be obſerv'd, that in Ciſterns the Force of the Water ought not to be taken from the Bottoms where the Pipe is ſoldered, but from the Superficies of the Water which is in them, as may be ſeen in the Ciſterns A and B, No 2. & 3. wherein the Water that is in B hath more Force, becauſe it is higher than A, although the Pipes are of equal Thickneſſes and Lengths. But of this much has been ſaid already.

Prop IX. *The Water naturally aſcends near to the Level of the Place from whence it did deſcend.* This Propoſition is very intelligible, and is as much as to ſay, that if there be a Spring, as B, the Water whereof enters into the Receiver C, and if there be a Pipe, as D, deſcending right down, or obliquely, the Water will aſcend therein to E, which is the Level or Height above the Veſſel C: And if the ſaid Veſſel be not full but to the Point F, the Water will not aſcend through the Pipe D, but to the Point G, the Level of the ſaid Point F; and although the Pipe coming from the Veſſel C, be not drawn ſo high, if the End of the Pipe through which the Water paſſeth be ſmall and the Pipe great, it ſhall aſcend to its Level; but according as the Ends of the Pipes through which the ſaid Water paſſeth are greater, ſo the Water is deficient in its Height. This may be ſeen in the Figure, by the ſmall Pipes X Z P.

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This Propofition has been already demonftrated by *Marriotte, Vid. Fig.* 6. No 3. of this 32d *Plate*, but this Demonftration of *De Caus*'s being fo very plain and eafy, I thought I could not do better than to infert it in its proper Courfe.

Prop. X. *Of the Syphon or Crooked Pipe by which the Water is drawn forth.* This Pipe is in Ufe in divers Places, and hath been treated of by *Hero* of *Alexandria.* But it muft not be here omitted, becaufe it falleth feveral Times in Ufe for our Subject, and alfo to underftand the Reafon thereof. This Pipe, then, is called by feveral, a Syphon, and hath that End which is without the Veffel, longer than the other; and if the Air be drawn forth which is within the faid Pipe, when it begins to run it will not ceafe till it has emptied the Veffel as high as the other End; and that which in Effect may feem ftrange, of the faid Syphon, is, that the Water rifeth higher than the Top of the Veffel by the faid Pipe, the Reafon whereof may be given thus: Let the Veffel be B, *Vid. Fig.* 15. *Plate* 32. and the Syphon C V X, and let the Top thereof be V, and the End V X longer than V C; then when the Air which is in it is drawn forth by the End M, the Water of the Veffel B enters therein to fill the Place. Now it being full, the Water contained from V to X, being more heavy than that from V to C, makes it run towards M; and as that Water cannot run out of the Pipe, unlefs there enter fomething therein to fill the Place, and the Air cannot enter the Water by any Place of the Veffel B, the Water will afcend till it comes to empty it felf to the Height of C, and then the Air entering therein, the Courfe of the Water will ceafe.

Prop. XI. *Of another Kind of Syphon, and how the Air may be drawn forth by the Means of another Veffel.* There may be made divers Kinds of Syphons; but behold here one which feems to be moft different, which neverthelefs depends upon the fame Reafon with the former. Let the Veffel be B, *Vid. Fig.* 16. No 1. *Plate* 32. and let the Pipe D C be foldered to the Bottom paffing through it: Then let one End of the Pipe A X Z be put about it, fo as the End X may be clofed and foldered fo as the Water may not enter but by A Z, but A Z muft not touch the Bottom: Therefore the Pipe A X Z muft be faftened to the Pipe D by two fmall Tennons, M and N, and it muft be obferved, that the faid Pipe A X Z ought to be made of fuch a Thicknefs that the Water contained between it and the Pipe D, may be equal to the Water which is in D; which being done, the Water may be drawn forth by D, and perform the fame Effect as the former. But if either the one or the other of thofe Syphons contains fo much Air that it cannot be drawn forth by Afpiration, there muft be made a Veffel, as P, very clofe, and foldered on all Parts, and it fhould have one End F to join with D, which Veffel, fill with Water, and join F and D together, without taking Air; then if you turn the Cock R, *Vid. Fig.* 16. No 3. the Water that runs forth from the Veffel P, will draw the Air of the Syphon, and make it run.

Prop. XII. *The Water runs equally by the Means of a Syphon, if the End by which the Water of the faid Syphon afcends, doth only touch the Superficies of the Water of the Veffel.* Becaufe that in the foregoing Pipes the Water runs not equally, being flower at the End than at the Beginning, it fhall be fhewn, in this Example, how it may run equally, that is, if to the End A of the Pipe A C, *Vid. Fig.* 12. No 1. *Plate* 32. a fmall Veffel of any Matter be put, let it be what it will, fo that it may float upon the Water, and the End A of the Pipe A C be put through the fame, fo as the End may touch the Superficies of the Water, it is certain, that the End C will run equally; which is not fo in other Syphons, which run always fwifter at the Beginning than at the End.

It will not in this Place, I humbly fuppofe, be improper to take Notice of an Enquiry that I have often heard made by fome ingenious Gentlemen, which is, Why Water will not always rife and run by the Gravitation of the Atmofphere, fo as that it may be tranfported from

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one Valley to another, as ſome Books of Engineering, and the general Notion of the Atmoſphere gravitating on every Thing below it, would make one believe.

In Anſwer to this, and to explain what I am about to deliver on this Head, it muſt be obſerv'd, that Air is of ſo inſinuating a Quality, that it will find its Way into, and deſtroy the Action or Gravitation of the Atmoſphere, by an Equilibrium, that for want of a repeated Suction in the aſcending Pipe or Pipes, it would otherwiſe indeed be in a continued Motion, and would with great Eaſe and Certainty convey the Water from one Valley to another.

To come to Example, (*Vid. Fig.* 18. *Plate* 32.) let A be the Valley from which the Water is to be tranſported through the higheſt Part of the Syphon B, and to run out at D into the oppoſite Valley. If (ſay theſe ingenious Enquirers) it ſhould be true that the Atmoſphere will raiſe Water 33 or 34 Feet, the Height of the Hill E, by B, into the Valley D, or lowerl, why if once exhauſted of the impeding Air, and ſet to work, will not this Syphon perform this Operation, this Tranſportation of the Water in an uninterrupted Manner? To this ſay thoſe that are experienc'd, that all or moſt Syphons, Springs, and Pumps, run always ſwifter at the Beginning, than at the End; for Air being elaſtick, and ſo confin'd to no Regularity, will be always inſinuating it ſelf at D, and taking its Courſe through the Pipe by B, and more Air inſinuating it ſelf through the Mole or Maſs of Earth, and crowded into all the Pores and Interſtices it can meet with, impedes and deſtroys the Aſcent of the Water, till by the Repetition of the Strokes by a Man or other Movement, plac'd ſomewhere about C, there is a new Suction of the intruding Air perform'd in the Pipe A C, which loſing its Force by that interior Exſuction, the exterior Air gravitating, as has been before deſcrib'd, on the Surfaces and Bowels of he Hill at or about A, riſes the Water over at B, as is before deſcrib'd.

We ſee even in ſmall Syphons, as Cranes, with which Wine is decanted, that the Inſinuation of the Air is ſuch, that Wine will not always keep on its regular Aſcent, without the Butler puts his Mouth ſometimes to it, to give it a new Suction; much leſs can it be expected that a Syphon or Crane 33 or 34 Foot high, and which is liable to be ſtopt by the leaſt Interpoſition of the Air, ſhould continue its Action without a continual Exſuction and Attendance. And this we know holds good in Pumps, Syringes, &c. which otherwiſe would be uſeleſs Engines; but if good, are call'd, Atmoſphere Pumps.

CHAP. XXXVI. *Amongſt the Works of the celebrated* La Bron, *I find a Gauge*, &c. This Gauge is deſcrib'd *Fig.* 22. *Plate* 32. and, as Monſieur *Marriotte* has it, p. 190. of the *Engliſh* Edition, may be eaſily calculated the Number of Inches which the River *Seine* gives: For ſince there paſſes under the Red Bridge in one Minute 200,000 Cubic Feet of Water, if we multiply 35, which is the Number of Pints which a Cube of one Foot contains, by 200,000, we ſhall have 7,000,000 Pints; which being divided by 14, give 500,000, which is the Number of Inches which the River *Seine* gives, when it is at a moderate Height.

If we have a Mind to calculate what Quantity of Water goes through large Paſſages, as through a ſquare Fathom, it is neceſſary to conſider the Height of the Surface of the Water, above the Middle of the upper Part of this ſquare Hole, through which the Water is ſuppoſed to run. Let it be, for Example, 5 Feet, there will be then 8 Feet from the Top of the Water to the Middle of the ſquare Fathom. The Product of 8 by 13 is 104, whoſe Square Root is very near 10 and $\frac{1}{5}$, as 13 is to 10$\frac{1}{5}$, ſo is 14 to 11 nearly: And becauſe a round Inch is 16 Times greater than a round Hole of 3 Lines, an Inch with 8 Foot of Water above it, will give 16 Times 11 Pints, or 176 Pints; which being divided by 14, give 12 Inches $\frac{4}{7}$ for an Inch Diameter of the Hole. A round Hole of one Foot Diameter, gives an 144 Times more; the Product of 12$\frac{4}{7}$ by 144, is 1810; the round or cylindric Foot then will give 1810 Inches. The round Toiſe contains

contains 36 Times a Cylinder of 1 Foot: The Product of 36 by 1810, is 65160; as 11 is to 14, so is 65160 to 82930. Then a Passage of a square Fathom having 5 Feet of Water above it, will give 82930 Inches.

From thence we shall find, that if the River *Seine* were stopt, when it is swell'd a little above its usual Greatness, and was rais'd 8 Feet above a square Hole, 10 Foot high, and 18 Foot wide, it would go all out through such a Hole: For there would be a Distance of 13 Feet from the Surface of the Water which was stopt, to the Center of the Circle, which would have 10 Feet Diameter; and it would give through an Hole of 3 Lines Diameter, an Inch of Water: Through one of an Inch Diameter, it would give 16 Inches; thro' one of a Foot, 144 Times 16 Inches, which makes 2304 Inches: And multiplying this Number by 100, the Square of 10 Feet, which is the Breadth of the Hole, we should have 230400; and according to the Proportion of the Circle to the circumscrib'd Square, which is of 11 to 14, we should find very near 293236 square Inches; and adding to it 8 Feet in Length, we should have more than 500000 Inches; which is what the River *Seine* gives at a moderate Height, as has been said before; and consequently it would all go out through a square Hole, which should have 18 Feet in Length, and 10 Feet in Height.

If Water runs through an Aqueduct, or through the Channel of a River, in a gentle uniform Declivity, it will acquire in a moderate Space a Velocity, which will increase no more: For the Friction of the Banks, and the Bottom of the Channel, and the Parts of the Water being turn'd over one another, and the Resistance of the Air to the little Waves which are in the Surface, cause it to lose a Part of its Velocity; and consequently it cannot accelerate its Motion, but to a certain Velocity which it acquires in a little Time. From whence it follows, that if a River has run through a pretty long Space in a certain Inclination, and that it runs afterwards in a less steep Inclination, that is to say, along a Plane less inclin'd, it will diminish its Velocity: For since it will have acquir'd in the first Inclination all the Velocity which it can have by it, and could not have been able to acquire by a less; it follows, that its Velocity will lessen by Degrees in that Inclination which is less, till it be reduc'd to that Velocity only, which it can acquire by this gentler Declivity.

Thus far *Marriotte*. And from these Rules it is, that an ingenious anonymous Author of our own Country, in his Account of Meteorology, calculates the Quantity of Water which runs through *Kingston* Bridge.

But that the measuring of Jets or Cadences of Water may be brought and apply'd to *English* Practice, it is necessary to look back on Chap. XXXIV. p. 381. towards the Bottom; where we shall find, that tho' a circular Hole of a *French* Inch, (*i. e.* 1 $\frac{1}{12}$ *English*,) give 72 *Paris* Muids or Barrels in 24 Hours, yet as the *Paris* Muid is not equal to our *English* Hogshead, though by some considerable Authors it is suppos'd to be, the same Inch of Water will give but about 55 Hogsheads and a Half in the same Time.

Again; when we calculate the Water which comes over the Head of a Cascade, or through a square Pipe or Trough, there is likewise some Difference, at least as 11 is to 14; from whence I lay it down as a general Rule, that though a circular Hole of 1 Inch Diameter give but 55 Hogsheads $\frac{1}{2}$, yet a square Trough or Pipe of an Inch will give 70 Hogsheads $\frac{7}{11}$, which is something more than Half a One.

Let there then be a Bay or Cascade of Water of 20 Foot wide, which is 240 Inches, and that the Water is regulated exactly to run or tumble over the said Bay or Cascade half an Inch thick, which is 120 Inches Square of Water, that Cascade will take (according to the foregoing Calculation) 11475 Hogsheads to supply it a whole Day, though where Water is brought by an Engine, or the Supply of the Spring be penurious,

penurious, the Playing of that Cascade 6 Hours, will be sufficient.

To regulate and make the Expence of Water that is to tumble over a Cascade very certain, and which is of great Use where the Water comes in a penurious Manner, the Right Honourable the Lord *Middleton*, at *Middleton* in *Warwickshire*, has made a Contrivance which I think proper to mention in this Place, because I never saw it in a Book, or elsewhere put into Practice, but there, and which will be sufficiently explain'd in *Fig.* 19. *Plate* 32. to this Chapter annex'd.

A represents the Canal from whence the Water comes, B the Head or Bay, made of Stone, and C C C C the Steps over which the Water falls: Now in the Head B there are seen 4 Holes, of what Diameter you please, into which Plugs are to be put, to keep the Cascade from running at all when the Water is scarce, or you have not a Mind to play it.

At the Bottom of the Head B there are Pipes which go under it, and communicating with the Canal A, are ready to spoute up their Water when those Plugs are taken away, but yet so as that it will not raise it higher than its own Level at A, but yet it will come out very quick, and the Cascade will abound with a greater or lesser Quantity of Water in Proportion to the Number of Pipes you open, or the Plugs you take away; sometimes, perhaps, the Water will be plenty enough to let you open one, sometimes two, sometimes three, and sometimes all four of the Holes.

I should before have noted, that the Water of the Canal A, is kept up to a constant Gage, by a thin Stone Work, or Valve of Wood at a a a a. Now at *Hampton Court*, and other Places, that Barricado is a Valve of thick Board, which is made to turn down when the Water plays; but then all the whole Water which is in the Canal, must of Necessity run off in a little Time, as low as the Bottom of the Valve; and if there be not a fresh Supply behind, its Action must soon cease; whereas in this Invention you can let on either more or less Water, as you see Occasion, and as your Supply will best allow. A murmuring or dropping of Water over such a Head, is amusing enough, but ¼ of an Inch Thickness is generally sufficient, and ½ an Inch thick of Water, the most that need be allowed to any, even the largest Cascades: For I have observ'd, especially where your Water is foul, that the Thickness of your Water rowling over a Cascade, is rather a Blemish, than a Beauty to it. Note, The Head of the Cascade ought to be at least 6 or 8 Foot thick, and made battering inwards, for every Foot high it ought to be at least a Foot thick at Bottom, to discharge the great Weight which must necessarily be laid against it.

Note ult. *A farther Account of the Distribution of Water from Pipes of Conduct, into smaller Pipes, for the Supply of Towns and Gardens, by Jets,* &c. The Diameter, Thickness, and Proportion, of Pipes of Conduct, Adjutages, *&c.* having been fully handled in p. 126. of this Treatise, there will be little or no Occasion for me either to capitulate or enlarge upon it in this Place. But the particular Method of distributing of Water for the Supply of Cities and Towns, and divers Parts of a Garden, with some particular Directions for keeping Pipes of Conduct, and Adjutages, clean, and from stopping up, and for the helping, if not the entire Prevention of that Friction and Interposition of Air which is the too natural Consequence of all Pipes that Water comes through, yet remains as necessary to be enlarg'd upon.

To know how to manage this Distribution well, let A B, *Fig.* 21. be the Height of a Vessel which is to serve for a Gauge, and C D the Height of the Water, you must place the square Holes about two Lines below the Surface C D, in an horizontal right Line E N. Now if this Gauge be divided into several Squares of an Inch every Way, as E F P H, *&c.* they will give more than an Inch; for if the circular Holes give 14 Pints in a Minute, the square ones will give a Quantity that will be to 14, as 14 to 11; which Proportion

portion of 14 to 11, is pretty near that of a Square to a Circle of the ſame Diameter: If then a round Inch gives 14 Pints in a Minute, a ſquare Inch will give almoſt 18 Pints; for 11 is to 14, as 14 to $17\frac{9}{11}$; therefore you muſt divide EF into 14 equal Parts; and if ER contain 11 of thoſe Parts, the long Square ERSH will be very near equal to a circular Inch, and it will give an Inch, that is to ſay, 14 Pints in a Minute, if the Water in the Gauge Veſſel continues at the Height CD. You may make ſeveral Holes regularly following each other, equal to ERSH, under the ſame Line EN, as RLTS, LMUT, *&c.* and if you would give Half an Inch, you muſt divide one of theſe long Squares, as OQIG, by a middle Line XY, and each Half will give Half an Inch, that is to ſay, 7 Pints in a Minute, and all the other Diviſions the ſame, if you take the Third, as IKZQ, or the Fourth, *&c.* There will be this further Advantage, that if the Water that ſupplies the Pipes diminiſhes, and paſſing through them, fills only a Third, or the Half, or two Thirds of the Height of the Holes in the Gauge, every Perſon will loſe in Proportion, which cannot be when the Holes are round; and if there be a little more Friction in the little Holes than in the great ones, the Water ſupplying the Expence through a narrow Paſſage better than a wide one, will compenſate that Defect. If you would give 3 or 4 Inches, you muſt take 3 or 4 entire Holes, each equal to ERSH, as LTUM; but you muſt make a little Separation, and have ſome Diſtance betwixt the Holes, when you give but an Inch to each Perſon; for their Waters would be confounded together, if there were but 2 or 3 Lines betwixt them; the Entrance into each Pipe muſt be wide enough to receive the Water of each Diviſion.

You may diſtribute a Spring to ſeveral Perſons in a Town, in this Manner:

Suppoſe that the Spring gives 40 Inches of Water in the Summer, and 50 Inches in the Winter, and 55 at other Times; you muſt make ſeveral Reſervatories, as FGHI, *Fig.* 21. where the Water may diſcharge it ſelf.

In the firſt, which muſt be the greateſt, you muſt let the Water riſe to a determinate Height, as AB, where there muſt be a Paſſage for the Water to run further on, and Holes for the firſt Diſtribution, as at CDE, a Foot below AB: Theſe Holes may be wide enough, taken together, to let 20 Inches paſs through, and the 25 remaining Inches will paſs above AB. It is evident, that when the Water is ſtrongeſt, the Elevation of the running Water will be greater above AB; and when the Water is weaker, that Elevation will be leſs; but not above an Inch, at moſt: So that when the Water that goes into the Reſervatory is 50 Inches, 20 and a half of them will go through the three Holes, and only about 19 and a half will paſs through them when the Water gives but 40 Inches. We will do the ſame in Reſpect of the Water that paſſes above AB and that that paſſes through the Holes; and make little Reſervatories in other Parts of the Town, where we may diſtribute to particular Perſons the 25 Inches, and the 20 Inches; always obſerving to make the Holes 12 Inches, or at leaſt 10 Inches below AB. At laſt, it will happen, that during the great Plenty of Water, there will remain 5 or 6 Inches of Water, which may be given to the Publick, in ſome unfrequented Place, for particular Uſes; and this Water will remain only during the great Plenty of Water; which may be obſerv'd alſo in the other Conduits, as CDE: For there will be always ſome Remainder for the Service of the Town, either for Fiſh-Ponds, or other Receptacles for Water, that are kept a long Time without any Addition of freſh Water, and which may be ſupply'd from Time to Time; the reſt will be equally diſtributed at the Rate of 45 Inches, only they will have ſometimes a little leſs, ſometimes a little more.

Frontinus, a *Roman* Author, has diſcourſed of theſe Conducts of Water after another Manner. What we call an Inch, he calls *Quinarta*; but his *Quinaria* was a little leſs: His Manner of applying what he

he calls *Calix*, at the Bottom of which, there was a little Pipe of the Bignefs of his *Quinaria*, does not feem to be juft; and it would be better to conduct 10 Inches to fome Part of the Town, if the Perfons in that Part want only 10 Inches, and to difcharge them into a long Refervatory, where fuch a Gauge as I have mention'd may be apply'd, that fhall give an Inch, or Half an Inch, according to what is got; and when there are Perfons that would have only a Line, which is the 144th Part of an Inch, or 2 Lines, which is the 72d Part of an Inch, then you muft make the Gauge different from that before-mention'd. There muft be made a little Refervatory apart, wherein the Water muft run fo as to lie always 5 Lines above the Holes; and having made a fquare Hole, whofe Side is 4 Lines, take away $\frac{3}{14}$ of its Breadth, leaving the whole Height of 4 Lines, which will give the 9th Part of an Inch, that is, 16 Lines. Half that Breadth will give 8 Lines, and a Quarter of it 4 Lines; or elfe you may make the Water to lie $6\frac{1}{2}$ Lines above a Hole of a Line fquare, from the Breadth of which you muft take $\frac{3}{14}$, to have the exact Contents of a round Line, which will exactly give $\frac{1}{14}$ of 14 Pints in a Minute, and 144 Pints in 24 Hours, of fuch Pints as are the 36th Part of a Cubic Foot. If you double the Breadth, you will have 2 Lines, which will give a *Muid* or Hogfhead in 24 Hours, or 12 Pints in an Hour, and 3 Pints in a Quarter of an Hour; and to be fure that fuch an Opening gives neither more nor lefs than two Lines, you muft count the Time in which the Water running through it will fill a Quartern; if it does it in 75 Seconds, the Quantity expended is exact. You muft let this Quantity of Water run in Pipes of an Inch Bore at leaft; for they might be ftopp'd up in Time, if they were lefs; and every 10 Years Care muft be taken that the Gauge-Holes do not fill with a ftony Subftance, which fixes to the Edges of the Holes; which, in fuch Cafe, muft be made a-new.

When *Marriotte* tells us that Conduct Pipes are not large enough, a fine Mud fettles in the loweft Part of them, which will fubfide even from the cleareft Water; and at laft, as it hardens, it will wholly fill up the Pipe: Therefore it will be neceffary now and then to open them at the loweft Places, fo as to make the Water run out with Violence, and it will bring out this Mud along with it, provided it be not yet petrify'd.

And that if a Conduct Pipe is to be carried over fome rifing Ground, there muft be a fmall Pipe folder'd to it in the higheft Place with a Cock to it, that is to be opened now and then, to let out the Air; which being drawn down with the Water, gathers together in the upper Part of the Pipe, and being condens'd by the Water which compreffes it, comes out in Bubbles, and ftrikes fometimes with fuch Violence againft the Conduct Pipe, as to crack it, if it be not ftrong enough to refift; or breaks Pieces out, if it be made of any brittle Subftance.

But for the Prevention of this, there are fome Rules laid already down in the Chapter which relates to Pipes in the Beginning of this Treatife, which is, by foldering on of hanging Valves at certain Diftances, which Valve hangs like the Lid of a Brandy Quartern, when there is no Water in the Pipes; but when the Water comes in, it will take the Sediment with it, and drive it and the Air on before, till the Pipe is fcower'd and clean'd: And as foon as the Water advances on in the Pipe towards the Place where the Valve hangs, the Air (there being another Pipe folder'd on, which reaches quite up to the Top of the Ground that the Pipe is cover'd with) will by the fuperior Force of the Water give Place, and take its Way out, giving the Water Room (without Interruption) to purfue its Courfe, and the Valve is thereby kept fhut till the Water retires again, and comes no more. This I owe to Mr. *Edwards*.

To go on: *Marriotte*, as to the Diftribution of Water; which is partly inftrumental, and partly numerical; which if any Learner would reduce to *Englifh* Meafures, he muft have Recourfe to the Beginning of this Fourth Book, p. 360, 361. where the *Englifh* and *French* Meafures are ftated and compared one with another.

 But

But for the better Calculation of the Diſtribution of Water to ſeveral Fountains or Houſes which will often want to be ſupply'd at one and the ſame Time, the following Method, which is entirely numerical, will (with humble Submiſſion to thoſe who like a mathematical Demonſtration better) be much ſhorter and eaſier.

Suppoſe-then, that there is a Reſervoir which is to play ſeveral Fountains, or ſupply ſeveral Houſes at one and the ſame Time, the Pipes of which are to be of different Dimenſions, according to the Largeneſs of the Fountains or Houſes the Reſervoir is to ſupply: And let there be ſix Branches to go from the Main, of the following Dimenſions; one of 1 Inch Diameter, one of $1\frac{1}{2}$, one of 2, one of $2\frac{1}{2}$, one of 3, and one of $3\frac{1}{2}$, or of any Dimenſions.

In the firſt Place, you are to find out the ſuperficial Content of the Bores of all theſe Pipes added together, which being multiplied as before directed,

		Inch.
The Content of Pipe No	1 is	1
	2	2
	3	4
	4	6
	5	9
	6	12
Which added together, is		34

Now to find out the Dimenſions of a Pipe of Conduct which is to ſupply all theſe Pipes at one Time, you are to take the neareſt Square of 34 Foot, either by Rules ſet down for that Purpoſe, or by the Table, which is to be found p. 377. of this 4th Book; where it will be ſeen, that the neareſt Square in whole Numbers is 25 Inches: But then there is the Square of 9 Inches more to find out, which is 108 Parts, the Square whereof is eaſily found out to be 10 Parts. See the Proof.

	In.	Pts.	
	5	10	
	5	10	
5 Inches by 5 Inches, is	25		
5 Inches by 10 Parts, is	4	2	
5 Inches by 10 Parts, is	4	2	
10 Parts by 10 Parts, is		8	4
	34	00	4

By which it appears, that the Diameter of ſuch a Pipe of Conduct is to be 5 Inches 10 Parts: But if it is 6 Inches, or 6 to 4, the better, upon Account of the Sediment, which is apt to happen in all Pipes; which, together with the impervious Air, Friction, &c. will (as has been before prov'd) very much impede or hinder the Spouting of the Water.

I might in this Place have added much more as to the Shape or Form of the Pipes at the Place where the Adjutage or Spout is join'd to them, and of the different Sorts of Figures which the laſt are made of, to make the Water appear above in various Figures, of all which *Bokler* has produc'd a Number of Varieties; but as all theſe Gimcracks are now in a great Meaſure out of Uſe, and there being no particular Shapes made uſe of, the Water riſing only in Columns or Mountains, out of ſingle large Adjutages, or out of an Adjutage which has one large Hole in the Middle, and ſeveral ſmall Perforations or Holes, ſuch as is ſeen *Fig.* 20. *Plate* 32. no more need be added till we come to the Practice of Water-Works in the ſeveral beautiful Plates that come from *Italy* and *France*, and which by and by follow.

Fig. 20. *Tab. prædic.* is a ſmall Plan of the Head or End of an Adjutage, the Top whereof is made of ſtrong Copper, of 1 Foot Diameter, the middle Jet is 2 Inches, the ſecond Row 1 Inch, the third Row $\frac{1}{2}$ an Inch, the fourth or out-ſide Row $\frac{1}{4}$ of an Inch.

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A.

B.

F I N I S.